The Engineer

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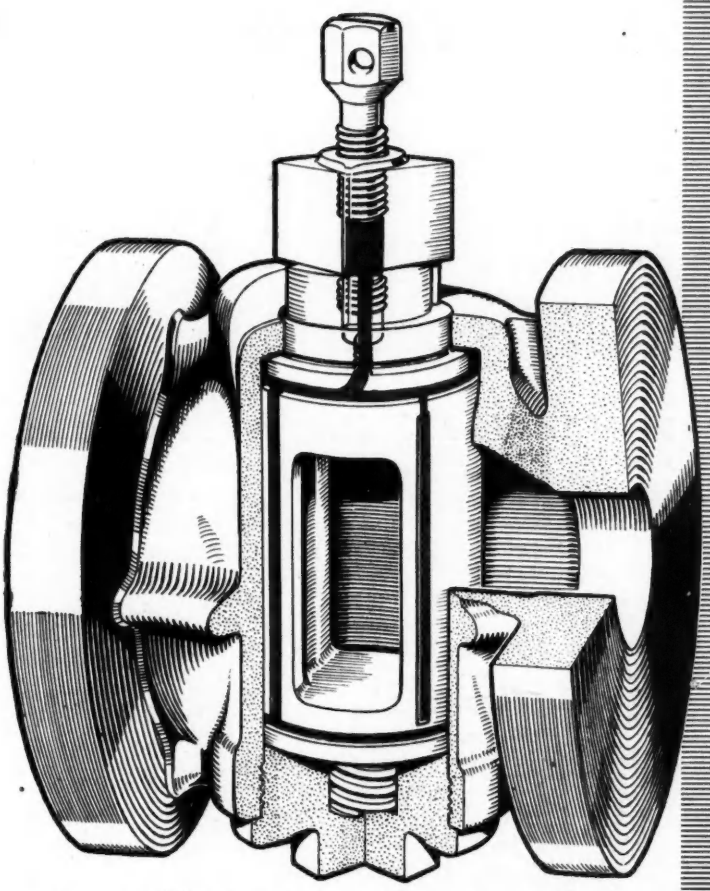
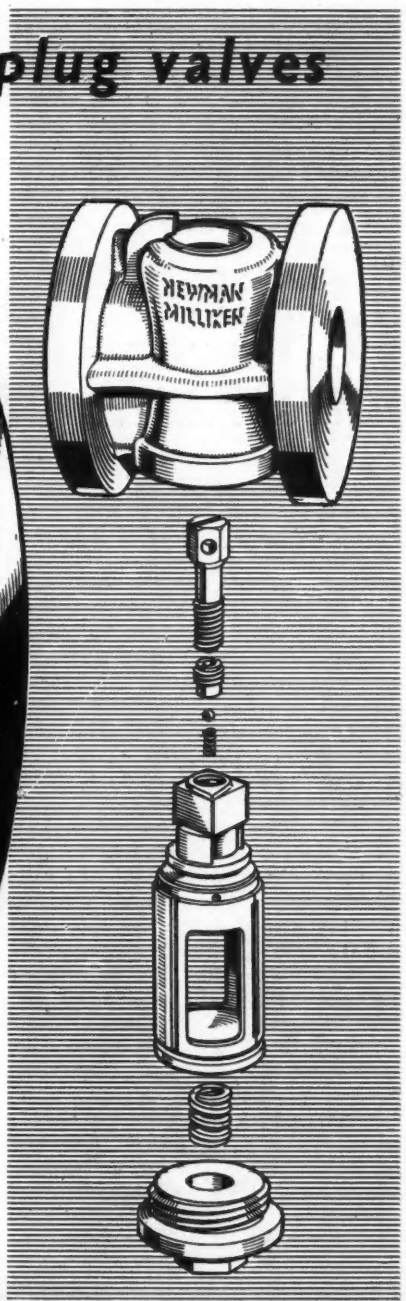
Newman - Milliken

Glandless lubricated plug valves





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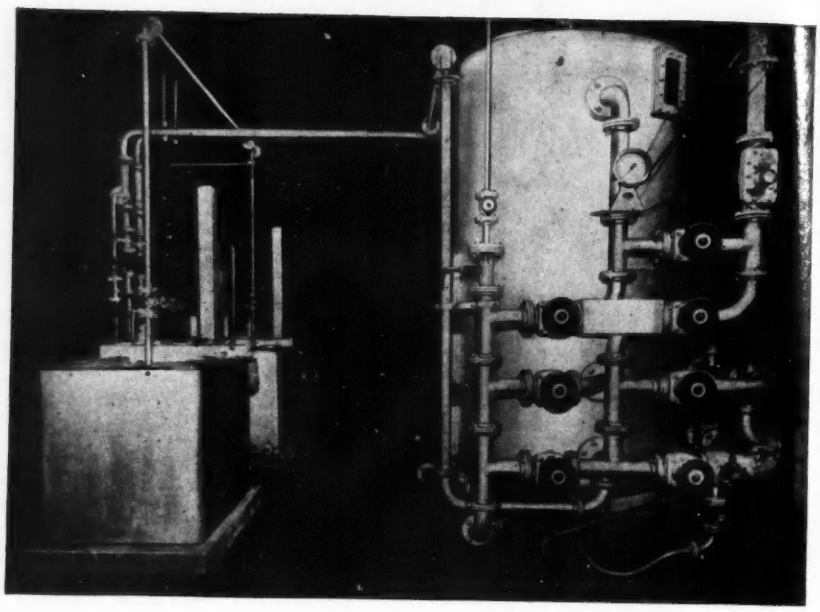
for the production of absolute water



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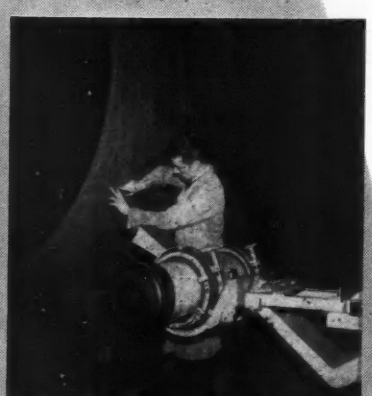

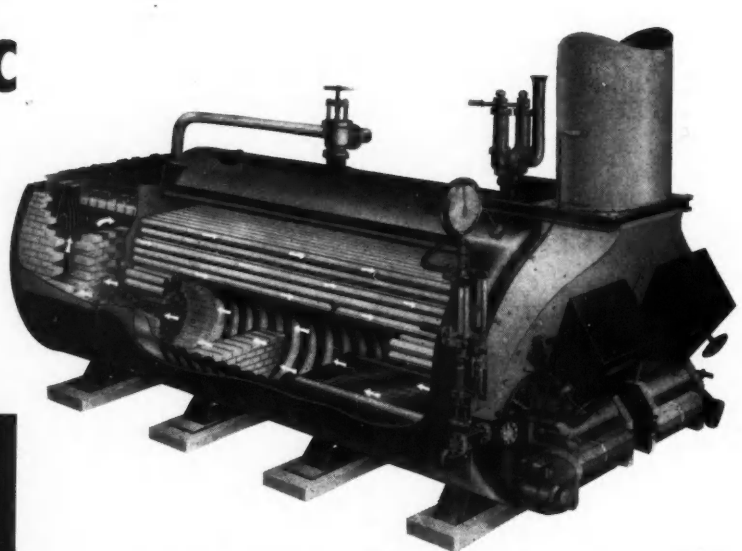

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THE ENGINEER

VOL. 202 No. 5264 DECEMBER 14, 1956

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OIL, ECONOMICS AND NUCLEAR POWER

There is no point at the present time in discussing how long the present oil shortage will last. Not nearly enough is known about the state of the Suez Canal or about arrangements that still have to be made to clear its channel for shipping ; and as for the oil pipeline whose pumping stations in Syria have been destroyed there is little to go upon save rumours contradictory in tone, that the Syrians wish to have the oil flowing again as soon as possible in order to draw royalties and that they wish nothing of the kind in order to embarrass Iraq ! One thing only seems firm. Arrangements are being made to facilitate the flow of oil from the Western hemisphere to Europe. But at best it seems unlikely, until such time as the canal is cleared, that the total oil inflow into Europe will exceed 75 per cent of the demand prior to the emergency. It does not, of course, necessarily follow that usage must be cut by 25 per cent. Stocks are believed to have been high and can no doubt be drawn down. But how rapidly they can be allowed to fall must depend upon estimates of the time that will expire before oil supply conditions return to normal. The Government's aim appears to be to cut oil consumption by about 10 per cent.

It is our impression that engineering firms will be inconvenienced rather than seriously embarrassed by the oil shortage. Nowadays there are relatively few firms that generate more than a small fraction of the power they need. Most of it comes from public electricity supply. The major difficulty is likely to be met in factory heating. Firms depending on oil fuel for this purpose may have to accept lower standards this winter or find means of turning over to the use of solid or gaseous fuels. Fortunately coal stocks at the beginning of this winter are unusually high, so that a somewhat enhanced demand can be met with safety. But let us pray that the winter is not a harsh one ! Another effect upon the work of engineering factories will arise out of shortage of road transport fuel. But again it seems probable that the difficulties can be overcome at a cost in inconvenience rather than of output. Some goods that would normally be sent by road will have to go by rail. Ingenuity will have to be displayed in ensuring that lorries are kept as fully laden as possible even if a certain amount of time is wasted thereby ; and executives, instead of having a works car at call, will need to arrange their affairs to fit in with scheduled trips. Output should not be seriously affected by the need to make such arrangements. A much more serious threat to output stems from the possibility that the flow of raw materials into engineering factories may be upset. Steel works, for example, have been increasingly turning over to oil fuel for many years past. It seems very unlikely that the trend can be reversed without loss of output. That situation is all the more unfortunate because supplies of steel were already tending to run short of demand before the emergency arose. But if the engineering industries can accept the fuel situation with reasonable composure there are other aspects of the emergency which are far less reassuring. On the business side high shipping freights, the increased length of a voyage to the Near East, India, and even Australia and New Zealand, and lack of shipping space must adversely affect the delivery of exports from this country and the arrival of imports. Precisely what the effect will be on the balance of trade cannot yet be seen. The November figures indicate that the initial effect has been to reduce imports but not exports. It hardly seems probable, however, that so favourable a consequence can persist. Yet it is particularly desirable that the trading figures of this nation should be favourable in the next few months. For an economic situation in which last month the sterling area's reserves fell by almost £100 million can only be restored to normality by the recovery of confidence amongst other nations in the stability of the pound. If trading figures indicate that the country is in fact paying its way—and providing that possible forthcoming wage increases are held back to very moderate figures according reasonably well with increases in productivity—confidence will, we think, readily return.

But the whole affair has, of course, shaken the confidence of this country and of others in Europe that ample supplies of oil can be guaranteed for the future. Can we really count upon a full, satisfactory and lasting settlement of the Middle Eastern situation ? Ought we not to attempt to reduce our dependence on oil ? A somewhat similar line of thought led between the wars to the coal *v.* oil controversy for the propulsion of naval ships. But the Navy held steadfastly to the view that if it could not ensure the arrival of oil supplies in this country neither could it ensure the arrival of food, that is, that there was no advantage to be gained by dependence upon coal mined at home. If it held command of the sea the war could be won and the oil fuel would be available. If it lost command of the sea the war was lost

anyway. To-day, so dependent is the country upon oil fuel, much the same argument holds. We, therefore, feel that the present temporary shortage of oil should not unduly affect our thinking, the more so that it is very unlikely that coal supplies could be increased sufficiently to balance a loss of oil supplies and that so much of the country's transport is and must remain dependent upon liquid fuels. It seems to us, for example, that it would be wrong for British Railways to have second thoughts about the use of diesel motive power on the railways and unsound for the steel industry to modify its plans for conversion to oil-firing. The economic and practical arguments for those changes are soundly based. What is suggested by the emergency is that the development of nuclear power should be pressed forward ; and fortunately there are indications that the programme for nuclear power development can be accelerated. Indeed, the programme envisaged by the White Paper of February, 1955, is already quite out of date. The coming into operation of Calder Hall station combined with industrial eagerness to organise for the manufacture of nuclear power plant and rapid developments in design have greatly altered the situation. It is believed that an announcement will be made by the Government about an expansion of the programme next week.

MAN MUST MEASURE

The value of measurement, it might be supposed, needs no preacher amongst engineers. For advances in engineering techniques and in the development of engineering theory have clearly depended very largely in the past upon improvements in the science of measurement. The production of improved measuring devices has allowed engineers not only to make things more accurately but also to distinguish more exactly between the effects of numerous variables able to affect the operation of machines, tools and other devices. Yet human beings are always a little blind. They are always more inclined to accept things as they are, even though they may argue about how they might be bettered, than to seek out the precise knowledge upon which a real advance can be founded. Indeed, the disciplined route to the gathering of precise knowledge is often made a subject for laughter. The scientific method, it is suggested—not without some foundation in fact !—is a method of arriving, at much cost in time and trouble, at conclusions that could have been reached much more readily by the application of " common sense." What is overlooked, of course, is that the common sense approach can lead only to a reasonably watertight conclusion. It is a conclusion founded upon intuitive good judgment as much as logic. It is not demonstrably and incontrovertibly a consequence of the original assumptions upon which it is based ; whereas the scientific conclusion is. For ourselves we have a high respect for those who can exercise " common sense " ; we think it rare rather than common. Where information is scanty, when measurements cannot be made, when calculation is impossible it is invaluable. But it is far better to seek to measure precisely the influence of the factors involved and to attain thereby a means of reaching exact conclusions. Particularly is it better in the kind of democratic society in which we live. For, to-day, important decisions are almost all made by Boards, Councils, Committees or similar bodies. If arguments are based upon intuitive judgment then those who compose the decisive body, often preferring their own individual judgments to those of others, can disagree amongst themselves. Action is thereby impeded or altogether prevented. But if the appeal is founded upon precise measurement and followed by precise calculation there is little room for manœuvre in argument. Confident action follows.

Last Monday, before the Institute of Transport, Sir Charles Goodeve delivered the 12th Henry Spurrier Memorial Lecture. He chose as his subject " Man Must Measure," and the bulk of the lecture was devoted to the use of operational research methods for the illumination of subjects relating to roads. Probably in no other present field of human endeavour has so much been said and written, so many ideas been propounded and so little been done in this country. Each year large sums of money are expended upon propaganda designed to promote safety or to convince the Government that more money should be spent upon the building of new roads and the improvement of old ones. Much of the propaganda is based upon a rather naive use of police-gathered statistics and generates little conviction ; and what little is done is often mistaken. Correspondents, for example, have recently drawn attention in our letters columns to posters displayed on roadsides with the laudable object of encouraging careful driving but having in fact an opposite effect because distracting. Is there no way on the roads of distinguishing between what is good sense and what is bad ? Effectively to urge the Government and local authorities into action it is obviously necessary to measure and evaluate, to put into precise terms the value, as against a more easily determined cost, of doing anything, whether it be the building of a motor-way, the driving of a traffic artery through a city centre, the reconstruction of a road crossing or the siting of a sign. It is all the more desirable that definite figures should be available because neither the Government nor local authorities benefit directly themselves from their expenditure on roads and, in consequence, they are always likely to overlook the cost, to a multiplicity of road users, of economies they may make in their own expenses.

Fortunately, operational research holds out the hope that calculations much more definite than any possible at present may in the not distant future be possible. The Road Research Laboratory, to which Sir Charles paid a very well deserved tribute, has already shown, more particularly by its work on pedestrian crossings and vehicle rear lamps, that suitable observational and statistical techniques can provide factual material of real value. That body, three universities, the Metropolitan police, and a unit working in the Ministry of Transport, are all making contributions to the study of roads by statistical and operational research methods. If the country were to devote less money to propaganda and more to the development of thought and action upon these lines the sooner it would be likely to have roads better suited to its needs. But, as Sir Charles well knows, operational research methods are applicable over much wider fields. There is, we believe, not nearly enough appreciation elsewhere of its powers. Too often amongst engineers as amongst other men, too high a significance is assigned to a single figure or the results of a single test. How often, for example, is a company's Board unwarrantably depressed because a month's figures of output, costs, &c., show up unfavourably against those of the previous month? Do they ever call in a statistician to work out whether the variation has any real significance ? Again, it is a common and apparently desirable practice to test the products of a factory to ensure that they are in working order before they are sent away. A low percentage of failures is the aim. But has such a test any relevance to what the customer really wants to know ? Are not such tests often actively damaging to customer-manufacturer relations ? For if the device fails quickly in service the knowledge of the supplier that it was in working order when it left the factory can breed the unfounded suspicion that the customer has misused it. In fact, of course, it may be inherent in the design or a consequence of some operation in manufacture that a proportion of all the devices will fail early in service. A change of test procedure would not only reveal the fault but throw light upon the means of rectifying it. Two of the morals to be drawn from the work of operational research exponents are the unwisdom of founding conclusions upon too few facts, even though they seem in agreement, and the folly of too naive an acceptance of statistics.

A Seven Day Journal

Research and Road Traffic

THE twelfth Henry Spurrier memorial lecture was delivered before the Institute of Transport last Monday evening by Sir Charles Goodeve. Sir Charles entitled his lecture "Man must Measure." In the course of it, he showed that the growth of operational research and its wide acceptance by industry and government authorities, both in this country and in the U.S.A., was one of the satisfactory developments of the post-war world. Because the repetitive nature of events in traffic permitted high accuracy, Sir Charles said, operational research was rapidly coming into all branches of transport and particularly road transport. In this country, Sir Charles claimed, there was one of the best units in the world for such research in the traffic and safety division of the Road Research Laboratory, though the total effort available to that division was the equivalent of only about £100,000 a year, a very small sum compared with the national effort in road transport. Sir Charles went on to express his belief that the policy in recent years of allocating most of our limited road funds to maintenance instead of towards improving efficiency was due largely to the scarcity of people studying the science of transport. The mistakes of the highway engineer, Sir Charles added, might be no more common than those of any other class of engineer, but they were certainly more obvious! No science, Sir Charles urged, could progress and be useful without the help of the universities, both to train people and to develop new lines of thought. In three universities in this country—Durham, Birmingham and London—there were the beginnings of operational research into road traffic, or "traffic engineering," as it was called. Three schools were probaby sufficient, Sir Charles remarked, but they could each do with much more support. The primary need was for more students, and they would come forward when the advantage of knowledge of traffic engineering became more widely recognised. The other need was for money for scholarships and for the special operational equipment required for this particular class of work.

Use of Natural Gas in Scotland

IT has been announced that, as part of the Gas Council's programme of exploration for supplies of natural gas, the Scottish Gas Board proposes to carry out a prolonged test of the natural gas resources existing at Cousland, near Edinburgh. Presence of natural gas at Cousland was proved by an exploration well drilled before the late war. The precise extent of this reservoir has not been established with accuracy, but a well drilled by the Gas Council in 1954 showed that the field was restricted. By using the gas from the existing well it will be possible to observe pressure decline, by which a better assessment can be made of the advisability of drilling a neighbouring well in order to define more accurately the limits of the prospective formation. The closed-in pressure of the gas at the well head is about 600 lb per square inch; this pressure will be reduced by suitable equipment and the gas fed through a 4 miles long main to the gas works at Musselburgh, near Edinburgh. Here the natural gas will be mixed with coal gas and distributed to domestic and industrial consumers in the area. It is stated that if this test leads to commercial production, the utilisation of natural gas will result in a saving of some 5000 to 10,000 tons of coal a year.

Underground Urban Parking

A PROPOSAL for an underground park to hold 350 cars on one floor has been prepared for Finsbury Square, in the City of London, by Lex Garages, Ltd., in co-operation with the Borough Council. A part of the square is already excavated for underground air raid shelters, and engineering difficulties are regarded as slight. The floor of quality controlled concrete would be impermeable, and drainage would be by gravity into a sewer 24ft deep, which already carries the surface water of the area. Reinforced concrete pillars at 25ft centres will carry 3ft beams to support the "ground." Pairs of ramps would give access for cars from filling stations at opposite sides of the square. The surface would be occupied by a bowling green and three tennis courts. Special bays around the perimeter of the garage would accommodate the roots of plane trees. Pavilion facilities and a café are included in the amenities envisaged. Development of the square will require an Act to pass through Parliament: it is estimated that an investment of £250,000 would be involved, and that parking charges would be markedly lower than on public roads for stays of several hours.

The Engineer
100 Years Ago
(DECEMBER 12, 1856)

"THE STEAM COLLIERS' ASSOCIATION"

"It will be within the recollection of the majority of our readers that early last year 'The Steam Coal Colliers' Association' of Newcastle-on-Tyne, publicly offered a premium of £500 for the best contrivance for the prevention of smoke in multitubular boilers; and that one of the conditions was, that the plan which was considered to have merited the prize should not be patented. In consequence of this offer, a number of persons who had paid attention to the subject prepared, at considerable cost, plans and descriptions, which were duly lodged with the Secretary in accordance with the conditions expressed. Since that time, now more than twelve months ago, no decision has been made, or, at all events, *published*, with regard to the different plans, and, very naturally, the parties who have lodged their schemes with the Association are beginning to think that 'everything is not as it should be.'

"We have, during the last few months, received a great number of letters upon this subject, but we have hitherto abstained from giving them publicity, with the hope that the award would speedily be made. From inquiries we have made, however, we do not find that there is any great probability of an immediate decision, and we think we should be blameable did we any longer refrain from suggesting to the Association the desirability of bringing this matter to an early conclusion. Our attention is called to the fact that two of the judges appointed by the Association have recently taken out a patent for an improved furnace. Now we do not for one moment imagine that these gentlemen have taken unworthy advantage of the position they occupy, but we are sure that we have only to inform them that such has been suggested by others, to convince them that an immediate award of the £500 premium to one of the competitors would be not only convenient, but, under all the circumstances, most seemly."

Lloyd's Statistical Tables

LLOYD'S REGISTER OF SHIPPING has issued its *Notes on Statistical Tables*, 1956, which are based on the entries in the Society's Register Book at July, 1956. The gross tonnage of steamships and motorships of the principal merchant fleets of the world are listed and compared with the 1955 totals. Great Britain and Northern Ireland have a fleet of 19,546,000 gross tons, and the total for U.S.A. is 26,146,000 tons, including the reserve fleet of 14,000,000 tons, while Norway, Liberia, Italy and Japan have fleets of 8,035,000, 5,584,000, 4,197,000 and 4,076,000 tons respectively. The world total stands at 105,200,000 tons, representing an increase of 4,632,000 tons, while the increases of individual countries are: Liberia, 1,587,000 tons; Norway, 786,000 tons; Germany, 554,000 tons; Japan, 340,000 tons; Netherlands, 310,000 tons; Italy, 286,000 tons; and Great Britain and Northern Ireland, 189,000 tons. Since 1955, oil tanker tonnage has increased by 1,756,000 tons to 28,211,000 tons, and represents 26·8 per cent of the total tonnage and compares with 16·9 per cent in 1939. The main oil tanker fleets are: Great Britain and Northern Ireland, 5,349,000 tons; Norway, 4,660,000 tons; U.S.A., 4,210,000 tons; Liberia, 3,184,000 tons, and Panama, 2,067,000 tons, with Liberia and Norway registering increases of 828,000 and 488,000 tons respectively. The tonnage of ships propelled by turbine machinery and diesel engines increased by 2,070,000 tons and 3,178,000 tons respectively to 29,157,000 tons and 37,701,000 tons, while the total of ships fitted with steam reciprocating engines decreased by 658,000 tons to 36,326,000 tons. At 9,092,000 gross tons the total of coal-burning steamships represented a decrease of 755,000 tons, while the tonnage of oil-burning steamships increased by 2,209,000 tons to total 58,407,000 gross tons. Of the total world tonnage, 44,841,000 gross tons are to the Society's classification.

Development Engineers for British Railways

THE British Transport Commission has announced that, to further the railway modernisation plan, locomotive development and carriage and wagon development units are being established at Derby and Darlington respectively. These two organisations will work to the requirements of the Commission for the whole of British Railways; they are being equipped to initiate and carry out development work on a variety of subjects. Those subjects include, the Commission says, the technical performance, efficiency and economy of diesel locomotives; the design and experimental production of new designs of carriage and wagon components and equipment, including complete bogies, and new methods of heating and ventilating coaching stock. Furthermore, new ideas which may be inspired by new materials or processes will be continuously studied by these development units, which will collaborate with industry as necessary. The establishment of the development units has led to the following appointments being made:—Mr. E. A. Langridge, development engineer of the locomotive development unit at Derby; Mr. T. B. Maddison, carriage and wagon development engineer at the Faverdale works, Darlington; Mr. N. H. Booth, assistant carriage and wagon development engineer (design), and Mr. J. W. Wild, assistant carriage and wagon development engineer (workshop).

Let's Forget the Cycloid Tooth

By W. A. TUPLIN, D.Sc., M.I.Mech.E.

Generated involute gears, after fifty years of development, cover more than 99 per cent of the field of gearing. It is recommended that their acceptance in practice should also be recognised in technological terminology.

INACCURATE terminology is tolerable so long as one never needs to use it, but it is, at the very best, a nuisance to anyone who hopes to explain the subject of the terminology to someone else. In the search for an accurate replacement for a misleading term one sometimes finds that there is no real need to refer to the particular point at all and that is the happiest way out of the difficulty for the newcomer and for his teacher. For anyone who has grown old in the defective usage, however, any change is distasteful because of the mental inertia that is part of human nature. It is notable, moreover, that mere abandonment (as distinct from supersession) of a bad practice may create a resentment that seems to arise from a loyal tenet that age should command respect even when wrong.

A good example is the term "pitch diameter" applied to a toothed gear. At a British Standards Institution meeting of a committee charged with drawing up a glossary on gears there appeared at one stage to be a general feeling that this term need not be defined because everyone knew what it meant. Three persons who were very sure on this point were cross examined and showed that they had three different interpretations of it. As these were three men with long experience in gearing and had certainly influenced many others at work in the same field, it was clear that there were widespread possibilities (and even certainties) of confusion about this term. The only sure way of avoiding any consequences of such confusion is to avoid using the term.

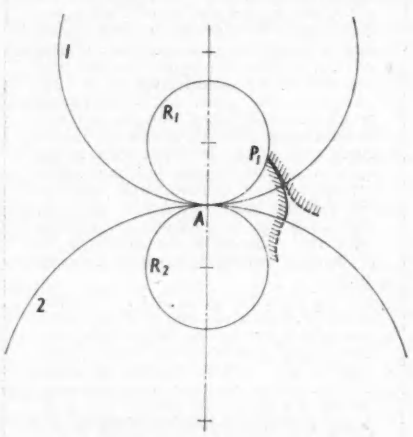
The origin of the practice of giving the name pitch circle to a particular circle in a gear is not far to seek. It never was a good term because even where it had any justification at all, it referred to a subsidiary attribute of the circle concerned and not to its fundamental character.

A pair of spur gears is a kinematic analogue of a pair of contacting cylinders with parallel axes separated by the same distance as those of the gears and having diameters in the ratio of the numbers of teeth in the gears. These cylinders roll together without slip if rotated at speeds equal to those of the corresponding gears when one drives the other by tooth contact. These cylinders are useful concepts in examining some aspects of the geometry and kinematics of the gears. Because of their distinguishing characteristic in this connection, the natural descriptive name for them is "rolling cylinders" and their intersections with any plane perpendicular to their axes would naturally be "rolling circles." This term was not used in the early history of gears and unfortunately cannot now be applied with safety because it was appropriated for two other rolling circles associated with the now almost obsolete cycloidal form of tooth. In preparing the British Standards glossary some other term was deemed necessary and the one selected was "meshing circles," which, so far as is known, has not been used (at all widely at least) to mean anything else.

In devising gear tooth forms on a rigorous basis of geometry and kinematics, it was natural to start from the meshing circles because of their kinematic importance in studying the action of the gears, when working together in mesh. A third circle (R_1 in the diagram) of arbitrary diameter was set in contact with the meshing circles and all three were imagined to have a common circumferential speed so that all three rolled together at A. During such action any point P_1 on the circle R_1 describes a "hypocycloid" on the rotating plane of circle 1 and this curve lies entirely within that circle.

Similarly P_1 describes an "epicycloid" on the rotating plane of the circle R_2, and this curve lies entirely outside that circle. It can be shown that if gear teeth are given these forms they will, within certain limitations, reproduce in the gears the condition of constant ratio of angular velocity that is a characteristic of cylinders rolling together without slip.

To avoid one of the limitations mentioned above it was found useful to employ a second



Geometry of the Cycloid Tooth

rolling circle R_2, and any point on this describes a hypocycloid inside circle 2 and an epicycloid outside circle 1.

On each of the circles 1 and 2 the epicycloid and hypocycloid merge nicely together by touching the straight line that contains the centre of the circle and the common point of contact of the two curves with the circle. In other words, a useful tooth form is the "cycloid" composed of an epicycloid outside the meshing circle and a hypocycloid inside the meshing circle with the characteristic that the tooth profile is radial at the meshing circle. One may say that the meshing circle is "built into" the gear by the mere fact of cutting cycloidal teeth.

But a necessary preliminary to producing gear teeth at all was to set out the tooth form on paper or on a board. The meshing circle was drawn. An epicycloid was drawn, starting from any arbitrary point on the meshing circle. A hypocycloid was drawn starting from the same arbitrary point on the meshing circle. Outer and inner limits of the profile were fixed by circles concentric with the meshing circle. The radius of the outer circle (the "tip circle") was made equal to that of the meshing circle plus an arbitrary amount called the "addendum." (Note the Latin influence.) The radial distance between the meshing circle and the inner circle (the "root circle") was called the "dedendum."

One flank of a tooth was thus fixed. How should one locate the corresponding flank of an adjacent tooth? The locating point of the first flank is the aforementioned arbitrary point on the meshing circle and its distance (measured along that circle) from the corresponding point on the next flank is equal to the circumference of the circle divided by the number of teeth that the gear is to have. Following established practice, this spacing distance was called the "pitch" of the teeth and before anyone could utter a minatory word, the circle became the "pitch circle."

So far as cycloidal gears were concerned this action had no serious consequences because the "pitch circle" (the one intersected at right angles by the tooth profiles) was bound to be the meshing circle. Unless the gears were set at the centre distance equal to the sum of the radii of the pitch circles, tooth action was imperfect. The circle upon which one naturally "pitched" the profiles happened to be the one and only possible meshing circle for the gear.

For the involute tooth form that is not the case. The fundamental circles of the involute tooth forms of a pair of gears are never the meshing circles. Moreover, an involute gear has no specific meshing circle when it is alone; it possesses one only when it is meshed with another gear at a particular centre distance. (If meshed with several gears at once it may have as many different meshing circles at the same time.) One may decide to apply the term "pitch circle" to some arbitrarily selected circle concentric with the base circle of the gear and when the gear is meshed with another one at some particular centre distance that "pitch circle" may chance to be the meshing circle.

The working part of a cycloidal tooth flank is convex near the tip and concave near the root. The profile is radial (near the mid-depth) at its point of intersection with the only possible meshing circle of the gear.

The working part of an involute tooth flank is convex everywhere. Only in imperfectly designed gears (apart from certain special exceptions) is any part of the working profile radial and the circle at which it occurs is never the meshing circle. At no point has any usable involute profile such unique significance as tangency to a straight line passing through the axis of the gear.

So far as was possible in the face of these radical differences, early practice with involute gears followed practices already used for cycloidal gears. As before, the intended meshing circle was first drawn and the pitch of the teeth on that circle established. Addendum and dedendum were fixed as artibrary multiples of the pitch just as was done for cycloidal gears.

It was soon found, however, that to follow cycloidal practice to the extent of making the profile radial at the meshing circle produced useless involute teeth. Inside the meshing circle one may draw a hypocycloid to work with an epicycloid on the mating gear, but there is no such thing as a hypo-involute.

Consequently, the involute profile was arranged to intersect the meshing circle at an arbitrarily selected angle which must be the same for the two gears of a mating pair if they are to mesh in the intended manner. This angle is the complement of the "pressure angle" which is the angle between the common normal to a pair of profiles at their point of contact and the common tangent to the meshing circles.

It was found that the action of a pair of involute gears was not impaired by changes of centre distance within a certain range

(they would not drive if one drew the teeth right out of mesh, for example). This meant that although the gears were unchanged, their meshing circles could be changed. How could terminology cope with this ?

In a laboured manner. The meshing circle for which the gear had been specially designed and which the profiles intersected at the arbitrarily selected angle was still called the " pitch circle," because that was what grandfather had called it. Any different meshing circle that the gear might have when meshed with another gear was called the " pitch circle of engagement " or the " running pitch circle." The identity in cycloidal gearing of the meshing circles with the " pitch circles " seemed so to have frozen thought on the subject that the word " pitch " came to resist abandonment as effectively as does its bituminous embodiment, and, in fact, it still sticks.

The value of the meshing circle in connection with study of the kinematics of tooth action is the same whether the gear has a thousand teeth or only one. In the latter case, there can be no question of pitch at all and so the misleading artificiality of forcibly adding the word " pitch " to the name of the circle is glaringly obvious. There is, in fact, more justification for calling the tip circle the " pitch circle of the tips " than there is for attaching the word " pitch " to the name of any meshing circle and especially as the tip circle of a gear is the one that can be identified with the greatest ease and without any doubt.

While involute gear teeth were produced by form cutters, tradition might be adduced as a reason for following cycloidal practice as an early step in the manufacture of a cutter is the setting out of the profile, broadly in the same manner for involute as for cycloidal teeth.

The introduction of generating processes, now used to almost complete exclusion of all others, in producing involute gears of quality, removed any necessity to set out tooth shapes on the drawing board. Analysis of the geometry and kinematics was facilitated by considering the meshing circles of the uncompleted gear and the cutter. In many cases, the meshing circle of the cutter is of infinite radius, or, in other words, a straight line, but the meshing circle of the nascent gear with a finite number of teeth is indeed a circle. Following established precedent, this was called the " pitch circle of generation."

In any involute gear the designed meshing circle (so-called " pitch circle "), the meshing circle in operation (so-called " pitch circle of engagement ") and the meshing circle with the cutter during generation (so-called " pitch circle of generation ") may be all different or they may be all the same. The one thing they always have in common is the superfluous and misleading word " pitch " in their ill-conceived names.

The wide variety of usable involute tooth forms that a single generating cutter may produce in gear-blanks of different diameters is in such utter contrast to the single-purpose character of a form-cutter, that terminology devised for the latter cannot fail to be unnecessarily restrictive and therefore misleading when applied to the former. An approach by the narrow paths of cycloidal-tooth usage, to an examination of the broad scope of generated involute gears is obviously unlikely to be the best way of seeing the picture clearly.

As in most branches of mechanical engineering, practical matters in gear manufacture and operation are of overriding importance. Viewing the generation of teeth of an involute gear as the sinking of a standard cutter to a specified depth in a blank of specified diameter while the machine gives appropriate relative motions to cutter and gear blank, and considering that all such gears generated by any one cutter will mesh correctly together at any centre distance approximately equal to half the sum of the blank diameters less the standard working depth for the cutter used, one soon realises that all practical requirements can be met without mentioning, or even thinking about, pitch circles, pressure angles, addenda or dedenda. This has not yet been recognised in any text book and as a consequence many who approach the subject of toothed gearing with a desire only to know how to fix dimensions for practical purposes, waste time and effort in trying to follow attempts to expound the widely adaptable generated involute gearing system in the archaic terms of the inflexible and obsolete cycloid system.

In certain calculations of dimensions of involute gears generated by a standard cutter, convenient use can be made of the diameter of the circle that the tooth profiles intersect at the angle that is the complement of the standard pressure angle. In British Standards parlance, this circle is the " reference circle."

Before generating processes were used, it was the " pitch circle " the " pitch circle of engagement " and the " pitch circle of generation " all usually contracted to the " pitch circle." In a fully utilised generated involute system, this " pitch circle " of any one gear may mean three different things. That this circumstance causes confusion to students of the subject is not surprising, and the fact that others after years of experience have learned to accept this confusion as normal is not an excuse for perpetuating it. To leave a deliberate stumbling block in the technique of a subject in order to discourage newcomers is an archaic artifice.

" Pitch circle " is not the only infelicity in gearing technology any more than gearing technology is the only one that contains terminological infelicity and a full account of the difficulties to be overcome in preparing a reasonably satisfactory glossary for toothed gearing would be very long. One other example may, however, be quoted of a term that deserves obliteration because of its uninformative and indeed misleading character.

The term " spiral gear " has been used to identify a cylindrical gear with helical teeth, meshed or intended to be meshed with another gear of the same description, the axes not being parallel. Not only does the word " spiral " fail to convey the information that the gear is an ordinary helical gear, but it strongly suggests that it is other than a helical gear as normally understood, else why should it not be called a " helical gear " ?

The term " crossed helical gear " is much to be preferred in that it avoids all the faults of " spiral gear " and conveys, or tends to convey, the fact that the gear differs from an ordinary helical gear only in that it meshes with its mating gear while the two have " crossed " or non-parallel axes. The term is believed to be of American origin, but that should not be made into a cause for showing it either favour or disfavour ; it succeeds by intrinsic merit.

In preparing a definition for inclusion in a glossary the aim must be to achieve the simplest form consistent with precision. In the British Standard glossary for gears, colloquial words are used wherever it is possible with precision. Nevertheless, a number of definitions have an academic flavour. Anyone who objects to this will find the British Standards Institution eager to receive amending suggestions but nevertheless ruthless in rejecting imperfect ones. Those who have sweated over the production of a bullet-proof definition of a " right-hand helix," for example, can make short work of shooting down any apparently simpler one.

There may have been an initial carefree approach to the definition of " wobble " (to take another example) based on the idea that as everyone knows what it means, there is no real need to define it at all. The reflection that the same thing has been said about " pitch circle " and with about equal truth prompted a more humble re-approach to the problem. If the result seems a little laboured that may be taken as a sign that someone has indeed laboured on it.

A British Standard may have many purposes and uses, but only if it says what it means. This demands a self-consistent glossary based, so far as possible, on accepted usage. But where accepted usage in terminology is inaccurate, misleading and self-contradictory, it excludes itself from any glossary produced by a body that claims to have studied the subject. Some definitions, if accurate, will inevitably appear stilted, pedantic or academic, which is another way of saying that their contrast with colloquial sloppiness is obvious even to the most faithful adherent to tradition. The British Standards Institution, as a body of international standing, would certainly mar its reputation if it appeared shaky on fundamentals or careless of precision in defining them. It is different in that respect from any individual because, on the one hand, it may be unimportant whether his talk or writing is loose or not, and, on the other, he may fail to convey conviction even if he advocates accuracy at all costs, where vagueness has previously reigned. But a national Standard on any subject concerned at all with precision should also set a standard in accuracy of expression.

Clearing the Suez Canal

A REPORT issued by the Admiralty states that current information makes it possible to prepare a reasonable assessment of the clearing problem and of the suitability of the ships and equipment now available. Before the canal is restored to normal, fifty-one known obstructions have to be cleared away, plus any wrecks not as yet located, and the sweeping of mines. It is considered that to make the canal function as a commercial waterway as early as possible the work of clearance should be carried out in three stages. Stage 1, it is suggested, should consist of making available a channel which would permit the passage of ships of 60ft beam and 25ft draught. This conforms with clearance already achieved at Port Said and will involve the removal of nine wrecks and two bridges, all of which are in Egyptian controlled territory. The next stage of the work should allow complete freedom of navigation to be possible, and with this achieved the third and final stage will consist of the tidying up of the berths and the disposal of the wrecks from the canal. The report emphasises the urgency of proceeding with stage 1, and suggests the best possible methods and the ideal ship for the work. Also included in the Admiralty statement are notes upon the availability and the general equipment of coastal and ocean salvage vessels, boom defence vessels, wreck dispersal vessels and survey vessels obtainable from Admiralty resources.

FIRE BARS.—A high-chromium heat-resisting steel, known as " Vesuvius," which has been developed by Firth-Vickers Stainless Steels, Ltd., for use at elevated temperatures, is stated to have a high degree of resistance to scaling at temperatures up to 1100-1150 deg. Cent. This steel is being widely used for cast fire bars in sintering plants, and we are informed that in one motor car works these bars had an average life of 1800 days' continuous service.

Myklestad's Method for Non-Uniform Vibrating Beams

By R. E. D. BISHOP*

No. I

The Myklestad method of tabular calculation is an extension of Holzer's well-known method for torsional vibration to the flexural motion of beams. It is a powerful method of vibration analysis and is shown here to be, essentially, a means of calculating the receptances of beams. The tables are presented in a form which is thought to be simpler to use than previous versions. A simple experimental check of the calculations that are used in describing this method confirmed their accuracy.

THIS article is concerned with tabular calculations which are usually associated with the name of Myklestad. The method was first published by that writer in 1944[1] and is described (with certain extensions) in his book.[2] The method of calculation was also developed and published independently by Prohl.[3] Not unnaturally, the techniques which were devised by these two authors differ in detail although they are identical in principle.

The method referred to is a powerful means of finding the natural frequencies and principal modes of non-uniform beams or the whirling speeds of non-uniform shafts. The beams or shafts may be continuous or overhung, they may be simply supported, clamped or free and they may support spring-suspended masses at intermediate sections. Again, in the whirling problem, allowance can be made for the gyroscopic effect. Several forms of complication can thus be handled and one, in particular, requires special mention; for, in a sense, it represents a first step in the direction indicated in the present paper. It is shown in Myklestad's book (page 199[2]) how the tabular method may be used in conjunction with considerations of "effective inertia" to find the natural frequencies of an aeroplane structure.

The reasons for presenting this article are twofold. First of all, the tables may be shown to be calculations of the receptances of (non-uniform) beams at specified values of frequency. Now the receptances of a beam are measures of its readiness to respond to harmonic excitation; they are thus of some limited importance for their own sakes. If they are known for a range of frequencies, then the natural frequencies and principal modes of the beam which lie within this range can be deduced.[4, 5, 6] It is for this latter purpose that the tables were originally intended and are now widely used in industry; but, apart from the flutter problem that has been mentioned, little emphasis has been laid upon the calculations as a means of allowing other properties of receptances to be used.

By evaluating receptances for a beam as functions of frequency, more is achieved than the acquisition of data on the beam's behaviour as an isolated vibrating body. In fact sufficient information is obtained as far as the beam is concerned to permit the calculation of (*a*) the receptances, (*b*) the natural frequencies and (*c*) the principal modes of any system of which the beam forms part.[7, 8]

The tabular method is essentially a development of the Holzer method[9] for torsional vibration of non-uniform shafts. But it is necessarily much more complicated than the Holzer technique since two co-ordinates (deflection and slope) must be used at each station along a beam, whereas one (angular deflection) suffices for a shaft.† This added complication is reflected in the complexity of the tables of both Myklestad and Prohl and it led the writer to investigate means of simplifying the book-keeping.

An attempt has been made to make the tables more nearly self-explanatory and this has entailed some experimentation with the lay-out and with the choice of quantities that are calculated. It may thus be found that, as they are presented here, the tables are less forbidding than before although, to be sure, they are still lengthy. The second purpose of this article is therefore to present the tables in a new form. It may be felt that this latter purpose requires some justification since a decision as to whether or not the tables are materially simpler must be a matter of opinion; and, in any event, a user of the method may be relied upon to work out his own salvation in this respect. However, while these points are certainly valid, it is equally true that the tables present a powerful and practical approach to problems which may be difficult to handle by other means. For this reason alone it may be useful to present the theory afresh, to give a survey of such literature as has grown up around it and to show the method in all its generality as a technique of analysis.

Basically, the method is to reduce a non-uniform beam to a system having a finite number of degrees of freedom by concentrating the mass distribution into an "equivalent" set of discrete point-masses. The flexural motion is then treated in terms of deflections of these masses.

The "Equivalent System" of Point-Masses for a Beam and the Errors that are Introduced by It

As stated above, the original beam is replaced for the purposes of calculation, by a system having only a finite number of degrees of freedom. The distribution of stiffness is not altered so that the original beam is replaced by a light beam having the same properties in flexure and carrying a series of particles to represent the mass of the original beam. If the stiffness of the beam varies continuously along its length,

Notation.

- b—Bending moment.
- E—Young's modulus.
- I—Second moment of area about flexural axis.
- l—Length of beam.
- M—Amplitude of bending moment.
- m—Mass of particle.
- n—Number of particles used in representation of beam.
- q—Generalised co-ordinate.
- r—Subscript used to denote the rth particle or the rth segment of beam.
- S—Amplitude of shearing force.
- s—Shearing force.
- V—Amplitude of deflection.
- v—Deflection.
- x—Distance along beam (see Fig. 3(*a*)).
- α—Receptance of beam using the following convention:
  - α_{rs} = amplitude of v at section x due to couple of unit amplitude applied in positive direction of θ at section $x=h$.
  - $\alpha_{r's'}$ = amplitude of θ at section x due to this couple.
  - α_{rs} = amplitude of v at section x due to force of unit amplitude acting in positive direction of v at section x.
  - $\alpha_{r's}$ = amplitude of θ at section x due to this force.
- ξ, η, ζ—Elastic constants defined as in Fig. 2.
- Θ—Amplitude of slope, θ.
- θ—Slope ($=\partial v/\partial x$).
- ρ—Mass density.
- ω—Frequency of excitation (rad/sec).

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† An explanation of how Holzer's method can be used to calculate receptances appears in Appendix II of reference[9].

TABLE I—$\omega = 1000$ *rad./sec.*

1		2	3		4		5		6		7		8	9	10	11
Section No. r		m_r	V (ft)		ΔS (entry $\times 10^6$ pdl.)		S (entry $\times 10^6$ pdl.)		M (entry $\times 10^6$ pdl. ft)		Θ (rad.)		l_r	ξ_r	η_r	ζ_r
Mass	Beam	(Lb)	Previous entry +18		$-2\times3\times(\omega^2\times10^{-6})$		Previous entry +4		Previous entry +19		Previous entry +14		(Ft)	(Entry $\times 10^{-6}$ ft/pdl.)	(Entry $\times 10^{-6}$ rad./pdl.)	(Entry $\times 10^{-6}$ rad./pdl.ft)
			Entry $\times V_1$ +	Entry $\times \Theta_1$	Entry $\times V_1$ +	Entry $\times \Theta_1$	Entry $\times V_1$ +	Entry $\times \Theta_1$	Entry $\times V_1$ +	Entry $\times \Theta_1$	Entry $\times V_1$ +	Entry $\times \Theta_1$				
1		0·0545	1·000	0·000	−0·0545	0·000	−0·0545	0·000	0·000	0·000	0·000	1·000				
	1												0·1667	0·07545	0·6791	8·149
2		0·1091	1·002	−0·1667	−0·1093	0·01819	−0·1638	0·01819	−0·009085	0·000	−0·03701	1·000				
	2												0·1667	0·07545	0·6791	8·149
3		0·1398	1·021	−0·3340	−0·1427	0·04669	−0·3065	0·06488	−0·03640	0·003032	−0·2222	1·012				
	3												0·1667	0·03090	0·2781	3·338
4		0·1704	1·073	−0·5046	−0·1828	0·08598	−0·4893	0·1509	−0·08749	0·01385	−0·4289	1·040				
	4												0·1667	0·03090	0·2781	3·338
5		0·1398	1·177	−0·6841	−0·1645	0·09564	−0·6538	0·2465	−0·1691	0·03901	−0·8570	1·128				
	5												0·1667	0·07545	0·6791	8·149
6		0·1091	1·460	−0·9079	−0·1593	0·09905	−0·8131	0·3456	−0·2781	0·08010	−2·679	1·613				
	6												0·1667	0·07545	0·6791	8·149
7		0·0545	2·126	−1·244	−0·1159	0·06780	−0·9290	0·4134	−0·4136	0·1377	−5·497	2·500				

as in an aeroplane wing, the elastic constants which are used for the length of span between a pair of adjacent point-masses may be found by the method proposed by Myklestad.[2] On the other hand, if the beam section varies in steps, as is the case with the lands on a shaft, the stiffnesses of the cylindrical portions may be calculated without difficulty; this is the problem with which Prohl[3] is concerned. The beam is first divided into lengths and the mass of each portion is concentrated either at its centre of gravity or is divided between the ends. With stepped shafts it is usually preferable, for the purpose of calculating the stiffnesses of the various portions, to adopt the latter course.

The mathematical treatment of the beam when it has been idealised in this way is "exact." Therefore the errors which are introduced in this form of analysis depend upon the number of point-masses used, their magnitudes and their distribution. It is convenient to divide the errors into two classes as follows.

Errors Which Arise Solely From the Use of a Finite Number of Masses.—As this number is increased, so the errors in calculated receptances diminish for any given value of excitation frequency. The higher the value of this frequency, the greater must be the number of point-masses for the same accuracy. The nature of errors of this sort has been examined analytically by Duncan[10] and by Livesley.[11] Both of these authors discuss the approximations to the natural frequencies of uniform beams (which may be obtained by the tabular method) by dividing the spans into numbers of equal portions. Livesley obtains the approximate relationship

$$\frac{{}^{\infty}\omega_s - {}^{m}\omega_s}{{}^{\infty}\omega_s} \doteq 0{\cdot}2\left(\frac{s}{m}\right)^2 \quad . \quad . \quad . \quad (1)$$

from Duncan's results where ${}^{\infty}\omega_s$ is the true value of the sth natural frequency and ${}^{m}\omega_s$ is the approximation to it which results from dividing the beam into m segments. This result was found for a uniform cantilever and is likely to provide a fairly accurate approximation for other kinds of support.

Errors Which Arise in the Selection of the Masses and Their Positions.—Consider one land of a stepped shaft (Fig. 1(*a*)). The simplest way of dealing with this is to treat the land as one segment of the length and to divide its mass equally between the sections as indicated in Fig. 1(*b*). The stiffnesses of this portion can readily be calculated in terms of the length l and diameter d as if the land were part of a uniform shaft. Now errors arise if this is done, since local effects at the steps influence the motion. It is not easy to estimate the magnitude of errors of this kind although they may outweigh those of the other class. The writer is not aware of any published treatment of this matter; an experimental investigation of it (with judicious use of the methods of dimensional analysis) would be of value.

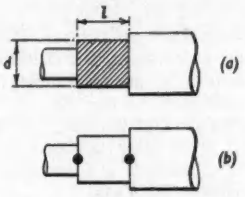


Fig. 1

It is difficult to say, with precision, how many masses should be used in the calculation of a receptance of a given beam for a specified frequency; for, as is indicated above, the degree of accuracy that is obtainable depends upon the way in which the cross section varies along the length. The following general rule appears to give reasonably accurate results for beams whose sections do not vary greatly. It is to aim roughly at having at least five particles between each point of zero amplitude of deflection v—that is, between each node.

The Flexibilities of the Beam Between Adjacent Point-Masses

When a suitable equivalent mass system has been chosen, it is necessary to determine certain elastic properties of the lengths of beam between adjacent particles. These quantities are "flexibilities" and they are three in number for each segment.

The rth segment of the beam is shown in Fig. 2; it may be of uniform or non-uniform section. Suppose that it is built-in at its left-hand end as shown in the diagram. If a shear force of unit magnitude is applied at the free end as in Fig. 2(*a*), it will cause the beam to deflect. Let this be such that the deflection is ξ_r and the slope is η_r at the tip. If this segment is uniform, then

$$\xi_r = \frac{l_r^3}{3EI_r}; \quad \eta_r = \frac{l_r^2}{2EI_r} \quad . \quad . \quad . \quad (2)$$

If, instead of the force, a terminal bending couple of unit magnitude is applied as in Fig. 2(*b*), then the deflection at the tip will be η_r in conformity with Maxwell's Reciprocal Theorem. Let the slope at the tip caused by this couple be ζ_r. If this portion of the beam is uniform, then

$$\zeta_r = \frac{l_r}{EI_r} \quad . \quad . \quad . \quad . \quad . \quad (3)\ddagger$$

It is necessary to determine the values of ξ_r, η_r and ζ_r for each segment of beam between the particles. If a segment is uniform

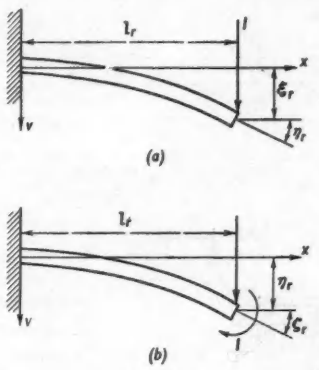


Fig. 2

then equations (2) and (3) may be used. On the other hand, if the beam section varies then a method that is explained by Myklestad (ref. 2, page 200), may be used.

The Method of Calculation Starting at a Free End

Consider the beam of length l shown in Fig. 3(*a*), which may be idealised in the manner already described to give that shown in Fig. 3(*b*). Let there be n particles attached to the latter. Let the masses be $m_1, m_2 \ldots m_n$, starting from the right-hand end $x=l$, and suppose that these are separated by lengths l_1, $l_2, \ldots l_{n-1}$ of the original beam. For the sake of explanation, it will be assumed that the end $x=l$ of the beam of Fig. 3(*a*) is free, the other end being free, pinned or sliding (but not clamped for a reason that will be apparent later).

The motion of particle 1 may be considered by imagining the beam to be severed just to the left of its point of attachment (Fig. 3(*c*)). The deflection and slope at m_1, namely, v_1

‡ In the notation of the "Vibration Analysis Tables"[12] (using the axes shown in Fig. 2)

$$\xi_r \equiv a_{11}; \quad \eta_r \equiv a_{1'1} = a_{11'}; \quad \zeta_r \equiv a_{1'1'}$$

where the a's represent the flexibilities of the rth segment of the beam.

TABLE I (*Continued*) $\omega = 1000$ *rad./sec.*

12		13		14		15		16		17		18		19	
				$\Delta\Theta$ (rad.)								ΔV (ft)		ΔM (entry $\times 10^4$ pdl. ft)	
5×10		6×11		12+13		5×9		6×10		7×8 / Next Line		15+16+17		5×8	
Entry $\times V_1$	+ Entry $\times \Theta_1$	Entry $\times V_1$	+ Entry $\times \Theta_1$	Entry $\times V_1$	+ Entry $\times \Theta_1$	Entry $\times V_1$	+ Entry $\times \Theta_1$	Entry $\times V_1$	+ Entry $\times \Theta_1$	Entry $\times V_1$	+ Entry $\times \Theta_1$	Entry $\times V_1$	+ Entry $\times \Theta_1$	Entry $\times V_1$	+ Entry $\times \Theta_1$
−0·03701	0·000	0·000	0·000	−0·03701	0·000	−0·004112	0·000	0·000	0·000	0·006170	−0·1667	0·002058	−0·1667	−0·009085	0·000
−0·1112	0·01235	−0·07403	0·000	−0·1852	0·01235	−0·01236	0·001372	−0·006170	0·000	0·03704	−0·1687	0·01851	−0·1673	−0·02731	0·003032
−0·08524	0·01804	−0·1215	0·01012	−0·2067	0·02816	−0·009471	0·002005	−0·01012	0·0008432	0·07150	−0·1734	0·05191	−0·1706	−0·05109	0·01082
−0·1361	0·04197	−0·2920	0·04623	−0·4281	0·08820	−0·01512	0·004663	−0·02433	0·003852	0·1429	−0·1880	0·1035	−0·1795	−0·08157	0·02516
−0·4440	0·1674	−1·378	0·3179	−1·822	0·4853	−0·04933	0·01860	−0·1148	0·02649	0·4466	−0·2689	0·2825	−0·2238	−0·1090	0·04109
−0·5522	0·2347	−2·266	0·6527	−2·818	0·8874	−0·06135	0·02608	−0·1889	0·05440	0·9163	−0·4168	0·6661	−0·3363	−0·1355	0·05761

and θ_1 respectively, will be assumed to have the values

$$v_1 = V_1 \sin \omega t$$
$$\theta_1 = \left(\frac{\partial v}{\partial \theta}\right)_1 = \Theta_1 \sin \omega t \quad . \quad . \quad . \quad (4)$$

where V_1 and Θ_1 are unknown constants and ω is the selected frequency for which a recep-

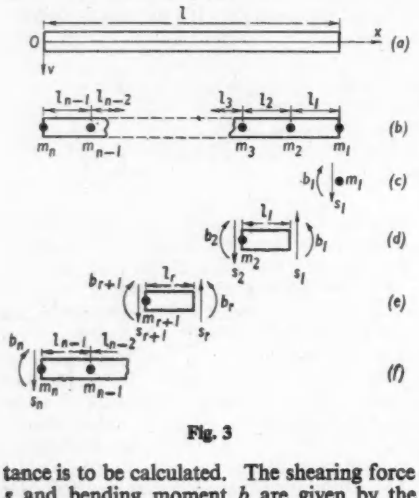


Fig. 3

tance is to be calculated. The shearing force s and bending moment b are given by the equations

$$\left.\begin{aligned} s_1 &= m_1 \ddot{v}_1 = -m_1 V_1 \omega^2 \sin \omega t = S_1 \sin \omega t \\ b_1 &= M_1 \sin \omega t = 0 \end{aligned}\right\} \quad . \quad (5)$$

Thus, with the assumed amplitudes of deflection and slope at mass 1, the amplitudes S_1 of shearing force and M_1 of bending moment can be calculated.

To proceed to the next particle, it is convenient to isolate the portion of beam shown in Fig. 3(*d*). The slope at m_2 is evidently given by

$$\theta_1 = \theta_2 - \gamma_1 s_1 - \zeta_1 b_1 \quad . \quad . \quad . \quad . \quad (6)$$

or

$$\theta_2 = \theta_1 + \gamma_1 s_1 + \zeta_1 b_1 \quad . \quad . \quad . \quad . \quad (7)$$

Thus,

$$\theta_2 = (\Theta_1 + \gamma_1 S_1) \sin \omega t = \Theta_2 \sin \omega t \quad . \quad . \quad (8)$$

so that the amplitude of slope may be found from the conditions at the preceding particle. The deflection v_2 may next be found from the relation

$$v_1 = v_2 - \xi_1 s_1 - \gamma_1 b_1 + l_1 \theta_2 \quad . \quad . \quad . \quad (9)$$

or

$$v_2 = v_1 + \xi_1 s_1 + \gamma_1 b_1 - l_1 \theta_2 \quad . \quad . \quad . \quad (10)$$

That is to say,

$$v_2 = (V_1 + \xi_1 S_1 - l_1 \Theta_2) \sin \omega t = V_2 \sin \omega t \quad . \quad (11)$$

From the amplitudes Θ_2 and V_2 of slope and deflection, it is now possible to calculate the shearing force s_2 and bending moment b_2 (Fig. 3(*d*)). These may be found from the equations

$$s_2 = s_1 + m_2 \ddot{v}_2 = (S_1 - m_2 V_2 \omega^2) \sin \omega t = S_2 \sin \omega t \quad . \quad . \quad . \quad . \quad . \quad (12)$$

and

$$b_2 = b_1 + l_1 s_1 = l_1 S_1 \sin \omega t = M_2 \sin \omega t \quad . \quad . \quad (13)$$

From the amplitudes V_1, Θ_1, it was first possible to find S_1 and M_1. It has been shown how the jump may then be made to the next particle and the amplitudes Θ_2, V_2, S_2 and M_2 calculated. In a similar way, this jump may be made along any segment of beam, the amplitudes being found in the order quoted; thus, in crossing the rth segment (Fig. 3(*e*)) it is found that

$$\left.\begin{aligned} \Theta_{r+1} &= \Theta_r + \gamma_r S_r + \zeta_r M_r = \Theta_r + \Delta\Theta \text{ (say)} \\ V_{r+1} &= V_r + \xi_r S_r + \gamma_r M_r - l_r \Theta_{r+1} \\ &\quad = V_r + \Delta V \text{ (say)} \\ S_{r+1} &= S_r - m_{r+1} V_{r+1} \omega^2 = S_r + \Delta S \text{ (say)} \\ M_{r+1} &= M_r + l_r S_r = M_r + \Delta M \text{ (say)} \end{aligned}\right\} \quad (14)$$

These relations form the basis of the tabular method as it is presented here.

When this calculation is started, two constants are needed whose values are left open, namely, V_1 and Θ_1. It is found that, in general, all of the amplitudes which are calculated subsequently depend upon these quantities through an expression of the form

$$AV_1 + B\Theta_1 \quad . \quad . \quad . \quad . \quad (15)$$

where A and B are constants. Therefore, in the tabular calculation, the columns for the various amplitudes are all double, containing the two multipliers, A and B.

The tabular calculations, of which an example is given later, proceed in the order indicated in equations (14) starting at mass 1, where the first entries are

$$\left.\begin{aligned} V &= 1 \times V_1 + 0 \times \Theta_1 \\ S &= M = 0 \\ \Theta &= 0 \times V_1 + 1 \times \Theta_1 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (16)$$

When the amplitudes S and M have been calculated for the station at m_1, it is convenient to move to a fresh line in the table to perform the calculations of $\Delta\Theta$, ΔV, ΔS and ΔM since they are associated with the first length of beam rather than with the station at mass 1. Having calculated these increments of amplitude, one can move to a new line to make the calculations of Θ_2, V_2, S_2 and M_2, which relate to the section just to the left of mass 2. And so the calculations proceed, ending up with the amplitudes Θ_n, V_n, S_n and M_n for the nth particle (Fig. 3(*f*)) each being given by an expression of the form (15). These represent conditions at the end $x=0$ of the original beam of Fig. 3(*a*).

The ways in which a table such as this can be used for the calculation of receptances will be described later on. Before this, a simple example of the tabular calculation will be presented.

Example of the Tabular Calculation

Fig. 4(*a*) shows a stepped bar which is free at its right-hand end; the method of supporting the left-hand end need not be considered at this stage. The material is steel,

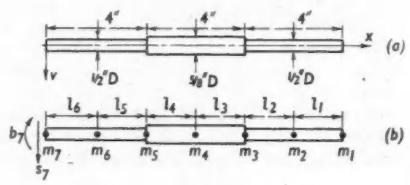



Fig. 4

for which the following constants are used :—

$$\left.\begin{aligned} E &= 13 \cdot 824 \times 10^{10} \text{ poundals/ft}^2 \\ \rho &= 480 \text{ lb/ft}^3 \end{aligned}\right\} \quad . \quad (17)$$

Pound (mass), feet, second units will be used throughout so that the unit of force will be the poundal.

The beam may conveniently be divided into six 2in lengths as in Fig. 4(*b*) for fairly low-frequency oscillation, although, of course, it is by no means necessary that all the segments should have the same length. These lengths are entered in column 8 of Table I.

The mass of each segment can now be calculated and divided equally between the ends of the segment. If the contributions from each pair of abutting segments are now added together, the values of the point-masses are obtained; they are entered in column 2 of Table I (page 838).

Columns 9, 10 and 11 of Table I contain the flexibilities ξ_r, γ_r and ζ_r for the various segments. These may be calculated by the use of equations (2) and (3), since each segment is of uniform section. Thus, for the portion of length l_3 the second of these quantities is

$$\gamma_{l3} = \frac{0 \cdot 1667^2}{2 \times (13 \cdot 824 \times 10^{10}) \times \left(\frac{\pi \times 0 \cdot 625^4}{12^4 \times 64}\right)} = 0 \cdot 2781 \times 10^{-6} \text{ rad./pdl.} \quad . \quad . \quad . \quad (18)$$

When the first entries in columns 3, 6 and 7 have been made the table is ready for use and the calculation may be started once a value of ω has been chosen. The value used in Table I is $\omega = 1000$ rad./sec.

The way in which the calculation proceeds is across the table from left to right. This follows the order of equations (14). However, it must be noted that in filling column 17 the value of Θ_r from the next following row is required in conformity with the second of equations (14). This value is readily available since $\Delta\Theta$ has already been found in column 14.

The Method of Calculation Starting at a Pinned, Sliding or Clamped End

The beam of Fig. 3(*b*) is redrawn in Fig. 5(*a*), this time with the right-hand end

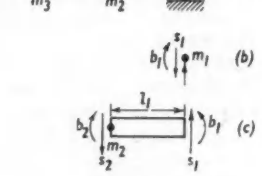


Fig. 5

pinned. The nature of the calculations is the same as before, although now not the deflection and slope at that end are unknowns, but the slope and shearing force.

Let the end slope again be

$$\theta_1 = \Theta_1 \sin \omega t \quad . \quad . \quad . \quad . \quad . \quad (19)$$

If the amplitude of the reaction is taken as S_1, equilibrium of particle 1 requires that the shearing force s_1 (Fig. 5(*b*)) shall be

$$s_1 = S_1 \sin \omega t \quad . \quad . \quad . \quad . \quad . \quad (20)$$

The remaining variables, v and b, at the section just to the left of particle 1 are both zero.

The passage from particle 1 to particle 2 may be made in the same way as before. Referring to Fig. 5(*c*), it is seen that equations (8), (10), (12) and (13) still hold good. Equally, in crossing the rth segment, equations (14) must still be used so that the tabular method proceeds just as before. All the amplitudes, however, are now obtained in terms of Θ_1 and S_1. The amplitude S_1 must now replace V_1 in columns 3, 4, 5, 6, 7, and 12–19 of the table therefore and the first entries are, for the station at mass 1,

$$\left.\begin{aligned} V &= M = 0 \\ S &= 1 \times S_1 + 0 \times \Theta_1 \\ \Theta &= 0 \times S_1 + 1 \times \Theta_1 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (21)$$

If, instead of being free or pinned, the right-hand end of the beam is permitted to slide so that its slope at that section is always zero, then the appropriate unknown amplitudes are V_1 and M_1. On the other hand, if the section $x=l$ is clamped, then the unknown amplitudes which must be carried through the calculation are S_1 and M_1.

(To be continued)

Calder Hall Heat Exchangers

The description of the Calder Hall heat exchangers given here is abstracted from a paper," Design and Construction of the Heat Exchangers," by H. Morris and W. R. Wootton, discussed at the Symposium on Calder Works Plant held by the British Nuclear Energy Conference in London on November 22 and 23. These abstracts deal with drum and tube-element manufacture, instrumentation and maintenance, omitting reference to the lifting of the shell and the clean-condition procedure for tubing out.

THE optimisation of the plant and the method selecting the steam cycle and conditions has been dealt with in the papers by Moore and Goodlet,* by Moore, and by Wootton. The main parameters associated with the heat exchangers are summarised in Table I, whilst Fig. 1 shows the temperature/heat diagram for a heat exchanger operating at full power.

TABLE I—*Gas and Steam Conditions for One Heat Exchanger at Full Load*

CO_2 gas flow rate, lb/sec.	491
Gas temperature at h.e. inlet	336 deg. Cent. (637 deg. Fah.)
Gas temperature at h.e. outlet	135 deg. Cent. (275 deg. Fah.)
H.P. steam flow rate (77 per cent total), lb/h	99,000
H.P. steam exit temperature	595 deg. Fah. (313 deg. Cent.)
H.P. steam exit pressure, lb/sq. in abs.	210
H.P. steam exit enthalpy, B.Th.U./lb	1,318·3
Power of h.p. circulating pump, h.p.	40
L.P. steam flow rate (23 per cent total), lb/h	29,650
L.P. steam exit temperature	350 deg. Fah. (171 deg. Cent.)
L.P. steam exit pressure, lb/sq. in abs.	62·7
L.P. steam exit enthalpy, B.Th.U./lb	1,207·4
Power of l.p. circulating pump, h.p.	12·5
Feed-water pressure at h.e. inlet, lb/sq. in abs.	340
Feed-water temperature at h.e. inlet	100 deg. Fah. (37·8 deg. Cent.)
Feed-water enthalpy at h.e. inlet, B.Th.U./lb	68·9
Feed-water flow rate, lb/h	128,650 (plus losses)
Heat taken up by water and steam, MW	46·15

Sectional elevations and horizontal cross sections of a heat exchanger are shown in Figs. 3 and 4. Each heat exchanger is supported on a skirt welded to the vessel itself and the whole assembly is mounted vertically on a reinforced concrete plinth to which the skirt of the vessel is bolted. The underside of the plinth is used to accommodate circulating pumps and ancillary gear associated with the heat exchanger. Gas from the reactor enters the heat-exchanger vessel through a 6ft diameter opening at the top and passes over the tube system in cross flow, leaving the bottom of the shell for the circulators.

Both the h.p. and l.p. tube systems, each consisting of superheater, evaporator and economiser sections, are contained within the heat-exchanger shell. This shell forms part of the gas-coolant circuit, and operates at 100 lb per square inch gauge. The steam drums and headers are mounted externally on the shell, and all interconnections between the various parts are also outside the vessel, the tubes being passed out of the shell through thermal sleeves. The geometrical details of a heat exchanger are given in Table II.

To provide the necessary heat-transfer surface economically the use of extended surfaces was essential. It was decided, therefore, to use elliptical studs electrically welded to the tubes. This application required the extrapolation of existing design data beyond the limit considered advisable and so a test rig was constructed in which both heat-transfer and pressure-drop characteristics could be determined experimentally. In this rig, hot gas was passed across various arrangements of tubes carrying water. By burning diesel oil in the suction of the fan hot gas was generated which passed over the tubes and up the chimney. The heating surface which could be accommodated in the rig amounted to some 600 square feet and gas flow-rates of up to 20,000 lb per hour square foot with thermal duties of the order of 1×10^6 B.Th.U. per hour were employed with mean temperature differences ranging from 100 deg. to 150 deg. Fah. (56 deg. to 83 deg. Cent.). The overall heat-transfer rates obtained were corrected for internal water-flow transmission and for tube-wall transmission, assuming a uniform heat flow through the tubes. Draught loss results were expressed in fractions of velocity head lost per row, based on arithmetic mean gas temperatures and mass velocity in the minimum free area. The curves developed for the selected arrangements of evaporator and economiser tube banks are shown in Fig. 2. The data from these curves were used in conjunction with the conservative figure of 2000 B.Th.U. per hour square foot deg. Fah. for the heat transfer to boiling water when calculating the evaporator surfaces, and the formula from McAdams† when calculating the inside heat-transfer rates for the economiser. Results from Pierson and Grimison‡ were used for the heat-transfer calculations associated with the outside surfaces of the superheaters, whilst the formula from McAdams† was used for the inside.

TABLE II—*Geometrical Details of One Heat Exchanger*

Main Shell :	
Length over flanges	73ft 4in
Overall length	77ft 4in
Inside diameter	17ft 3in
Thickness	1 7/8in
Gas inlet	6ft 0in diameter
Gas outlet	4ft 6in diameter
Steam drums :	
Length	19ft 7 1/2in
Inside diameter	4ft 0in
Thickness	11/16in
Headers:	
Outside diameter	10 1/2in
Thickness	1in
Tube banks :	
Economiser tubes	1 1/2in o.d. by 8 S.W.G.
Boiler tubes	2in o.d. by 7 S.W.G.
Superheater	2in o.d. by 6 S.W.G.
Gas volume :	
Live gas	7,370 cubic feet
Dead gas	6,600 cubic feet
Total gas volume	13,970 cubic feet
Heating surface areas :	
Outside of tubes in live gas:	
Superheater h.p.	4,450 square feet
l.p.	785 square feet
Evaporator h.p.	31,500 square feet
l.p.	31,500 square feet
Economiser h.p., h.t.	15,750 square feet
l.p., h.p.	15,750 square feet
Total	99,735 square feet
Inside of tubes in live gas:	
Superheater h.p.	3,580 square feet
l.p.	632 square feet
Evaporator h.p.	5,886 square feet
l.p.	5,886 square feet
Economiser h.p., h.t.	3,304 square feet
l.p., h.p.	3,304 square feet
Total	22,592 square feet
Outside of tubes in dead gas	925 square feet
Inside of tubes in dead gas	732 square feet
Length of tubes :	
H.P. superheater	152ft 6in per element, 9,764ft per bank
H.P. evaporator	253ft 9in per element, 16,143ft per bank
H.P. h.t. economiser	286ft 9in per element, 12,044ft per bank
L.P. superheater	59ft 3in per element, 1,898ft per bank
L.P. h.p. economiser	292ft 6in per element, 12,333ft per bank
Total length 1 1/2in o.d. tubing in banks	24,378ft
Total length 2in o.d. tubing in banks	43,949ft

The calculated steam conditions for the h.p. and l.p. systems, and performance under part load for the normal conditions of CO_2 temperatures entering and leaving the reactor maintained constant, are shown in Fig. 5. It will be seen that the output of the l.p. evaporating section falls as the load decreases, while the pressure rises, tending to equal that of the h.p. sections when the load is at a minimum. For

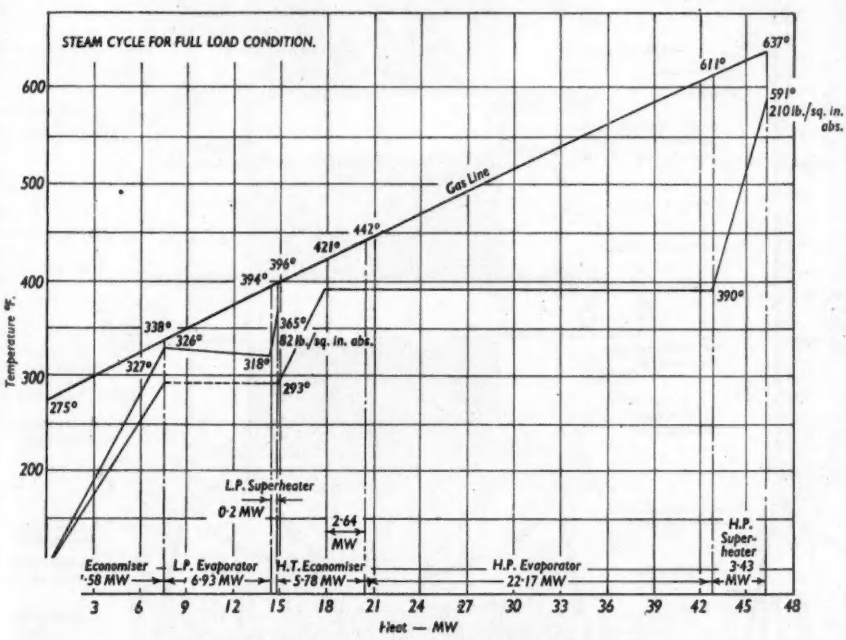


Fig. 1—Heat exchanger temperature-heat diagram

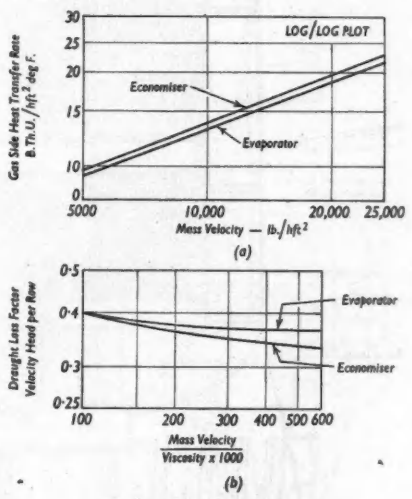


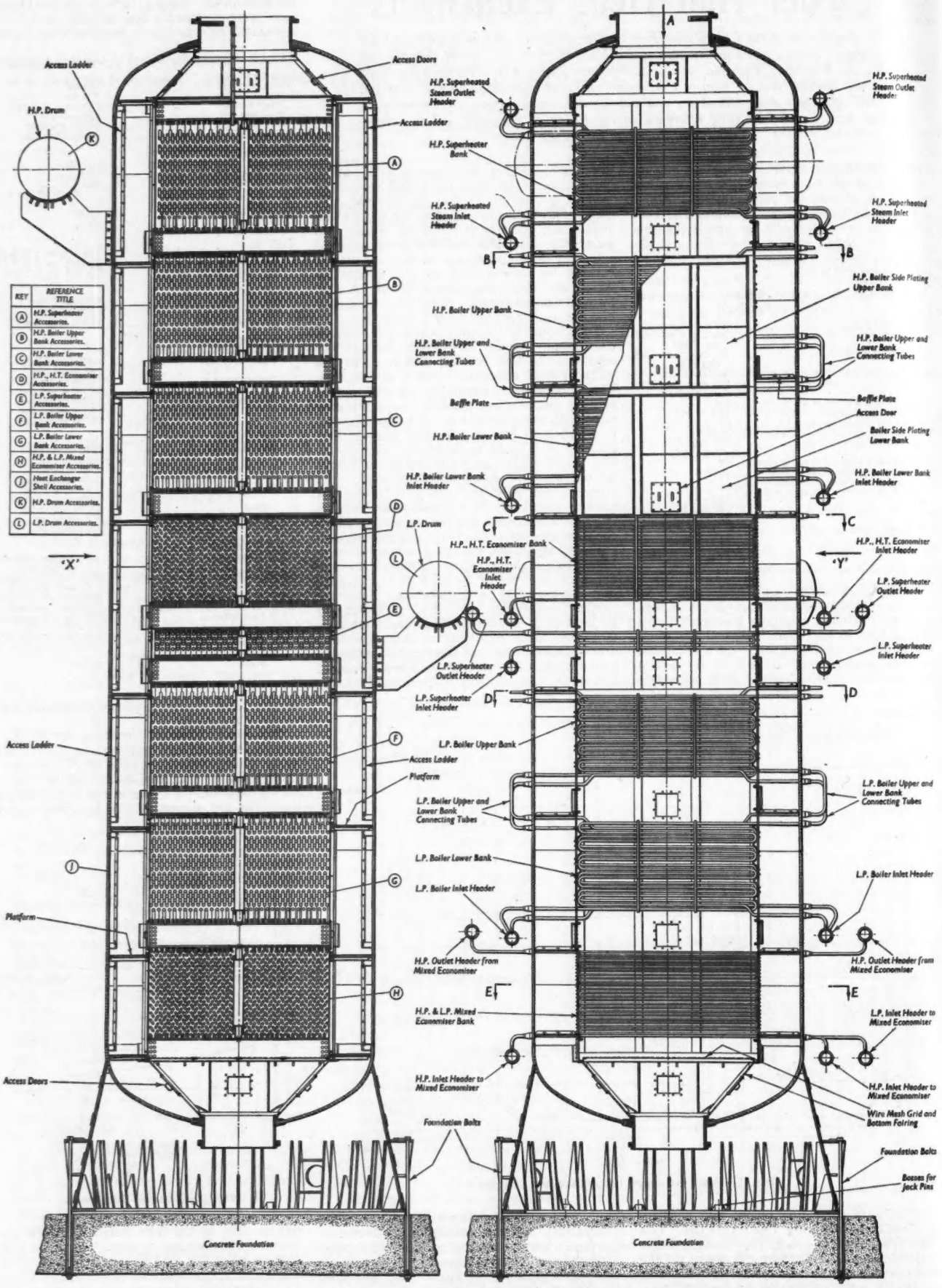
Fig. 2—Draught loss results

* "The 1951-53 Harwell Design Study," by R. V. Moore and B. L. Goodlet; "The Design and Construction of the Plant," by R. V. Moore. and "Steam Cycle Analysis," by W. R. Wootton. Symposium on Calder Works Nuclear Power Plant.

† McAdams, *Heat Transmission*, 1954, third edition, page 219, equations 9–10*a* (New York and London : McGraw-Hill Publishing Co., Ltd.).

‡ Pierson and Grimison, "Correlation and Utilisation of New Data on Flow Resistance and Heat Transfer of Gases Over Tube Banks," *Trans.* A.S.M.E., October, 1937.

CALDER HALL HEAT EXCHANGERS


KEY
REFERENCE TITLE
(A) H.P. Superheater Accessories.
(B) H.P. Boiler Upper Bank Accessories.
(C) H.P. Boiler Lower Bank Accessories.
(D) H.P., H.T. Economiser Accessories.
(E) L.P. Superheater Accessories.
(F) L.P. Boiler Upper Bank Accessories.
(G) L.P. Boiler Lower Bank Accessories.
(H) H.P. & L.P. Mixed Economiser Accessories.
(J) Heat Exchanger Shell Accessories.
(K) H.P. Drum Accessories.
(L) L.P. Drum Accessories.
'X'
'Y'
Access Ladder
H.P. Drum
Access Doors
H.P. Superheated Steam Outlet Header
Access Ladder
H.P. Superheater Bank
H.P. Superheated Steam Inlet Header
H.P. Boiler Upper Bank
H.P. Boiler Upper and Lower Bank Connecting Tubes
Baffle Plate
H.P. Boiler Lower Bank
H.P. Boiler Lower Bank Inlet Header
L.P. Drum
H.P., H.T. Economiser Bank
H.P., H.T. Economiser Inlet Header
L.P. Superheater Outlet Header
L.P. Superheater Inlet Header
Access Ladder
L.P. Boiler Upper Bank
Access Ladder
Platform
L.P. Boiler Upper and Lower Bank Connecting Tubes
L.P. Boiler Lower Bank
L.P. Boiler Inlet Header
Platform
H.P. Outlet Header from Mixed Economiser
H.P. & L.P. Mixed Economiser Bank
H.P. Inlet Header to Mixed Economiser
Access Doors
Foundation Bolts
Concrete Foundation
H.P. Superheated Steam Outlet Header
H.P. Superheated Steam Inlet Header
H.P. Boiler Side Plating Upper Bank
H.P. Boiler Upper and Lower Bank Connecting Tubes
Baffle Plate
Access Door
Boiler Side Plating Lower Bank
H.P. Boiler Lower Bank Inlet Header
H.P., H.T. Economiser Inlet Header
L.P. Superheater Outlet Header
L.P. Superheater Inlet Header
L.P. Boiler Upper and Lower Bank Connecting Tubes
L.P. Boiler Inlet Header
H.P. Outlet Header from Mixed Economiser
L.P. Inlet Header to Mixed Economiser
H.P. Inlet Header to Mixed Economiser
Wire Mesh Grid and Bottom Fairing
Foundation Bolts
Bosses for Jack Pins
Concrete Foundation

SECTIONAL ELEVATION LOOKING IN DIRECTION OF ARROW 'Y'. SECTIONAL ELEVATION LOOKING IN DIRECTION OF ARROW 'X'.

Fig. 3—Vertical sections through heat exchangers

this reason the design pressures of both l.p. and h.p. systems are identical, although the actual working pressures are 63 lb and 210 lb per square inch absolute respectively. It can also be seen that the h.p. steam pressure, accounting for the major proportion of the steam, remains constant throughout the range of load. Control of the h.p. steam is obtained by balancing the demand of the turbines with the flow from the heat exchangers, whilst the l.p. steam pressure is controlled through throttling valves. The paper by Anderson and Brown gives details of this control arrangement.

Heat-Exchanger Vessels

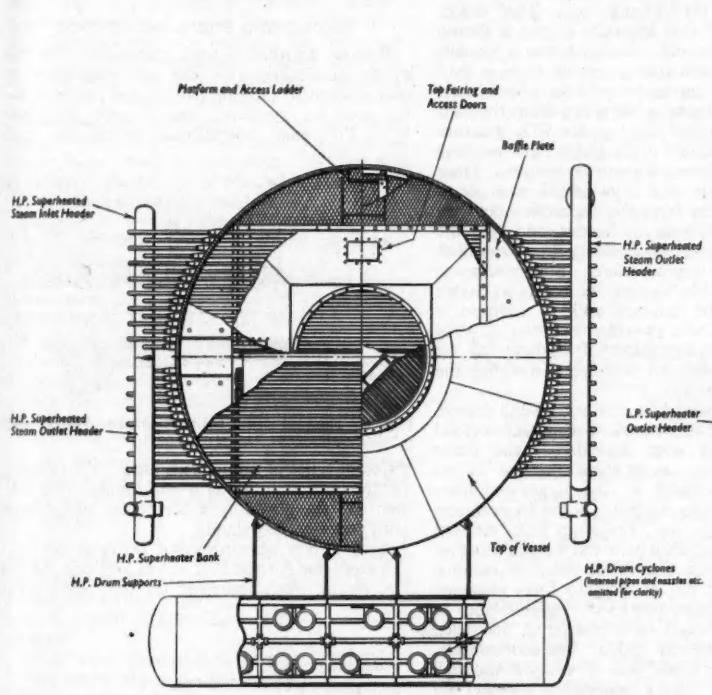
Because of difficulties imposed by its size the shell could not be transported between the manufacturer's works and the site in a single piece; instead each shell left the contractor's works in ten pieces, comprising a supporting skirt (itself in two pieces), two heads and six parallel sections. These sections were welded together in a workshop, taking two production lines, specially built for the purpose on site.

The heat-exchanger shell was designed in accordance with the A.S.M.E., Lloyd's and British Standard codes where these were applicable. Lloyd's Class 1 Rules for fusion-welded pressure vessels were applied throughout construction, each welded seam being fully examined by X-ray and stress relieved.

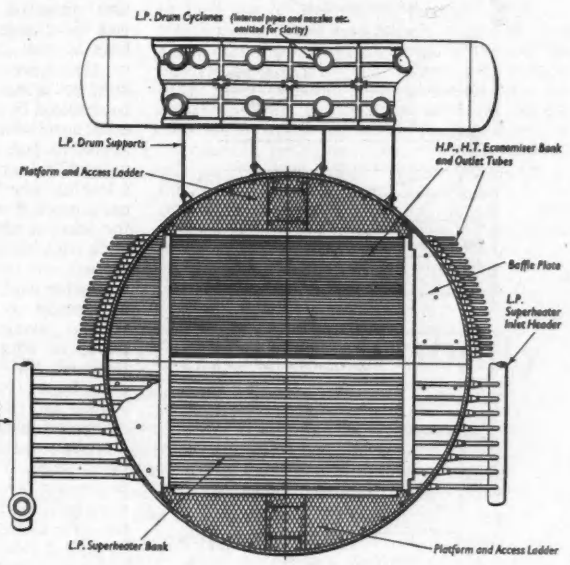
Good weldability, freedom from folds, laminations, and cold cracking were among the main requirements for the steel. "Coltuf 28" steel, which has an ultimate tensile strength of 28–32 tons per square inch, with a yield strength of 17 tons per square inch and an elongation of 25 per cent on 8in, was finally selected. This steel is deoxidised with aluminium and has a McQuaid-EHN grain size of 6/8. The plates were all supplied in the normalised condition, the thickness of the shell plates was determined at 1 $\frac{7}{16}$in, and the top and bottom domes at 1$\frac{1}{4}$in, a corrosion allowance of $\frac{1}{16}$in being allowed in these figures.

After shot blasting and marking-off the edges of the plates were machined to the weld preparation profile and then bent to shape and internally braced before being marked off in preparation for drilling the thermal sleeve holes. These were jigged-drilled for the reception of the sleeves themselves, as a high degree of accuracy was necessary for the subsequent fitting of the tube elements on site. The thermal sleeves were preheated to 100 deg. Fah. (38 deg. Cent.) before welding and during this operation were located on an internal tube fitted into the hole in the shell. After welding, this location tube was drilled out and the sleeve bored to the finished size. To prove the leak tightness of the weld the sleeve was blanked off using a special jig fitted with rubber joints and constructed so that an air line could be connected. A small amount of carbon tetrachloride was introduced into the sleeve with an air supply operating at 50 lb per square inch gauge and a British Thomson-Houston leak detector pistol was used to probe around the fillet weld. With this method of leak detection, background traces can adversely affect the sensitivity and a clean shop is necessary. The fumes from the coating of welding electrodes can also affect the readings obtained.

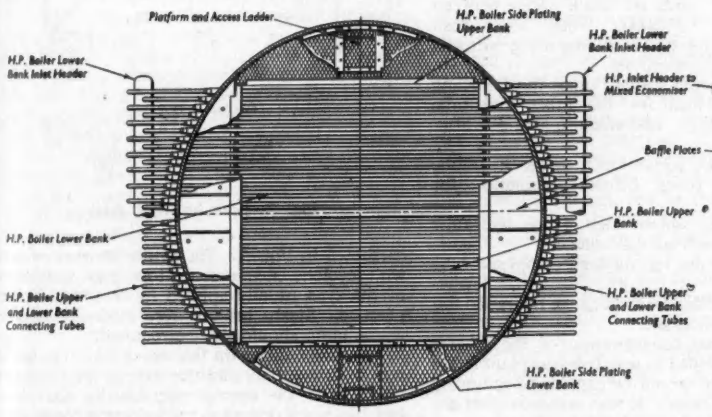
The two half-plates forming each course were placed on turning bogies at the manufacturer's works and after preheating to 100 deg. Fah. (38 deg. Cent.) the longitudinal seams were welded together and adjoining courses end-matched with each other. All supporting brackets for drums, headers and internal structures were fitted in place at this stage. The preparation for seams to be welded on site was of the deep "U" groove type. It was considered that this would enable more accurate matching of the sections to be attained, and permit the maximum amount of welding to be done outside the vessel. All


Platform and Access Ladder
Top Fairing and Access Doors
Baffle Plate
H.P. Superheated Steam Inlet Header
H.P. Superheated Steam Outlet Header
H.P. Superheated Steam Outlet Header
H.P. Superheater Bank
Top of Vessel
H.P. Drum Supports
H.P. Drum Cyclones (Internal pipes and nozzles etc. omitted for clarity)

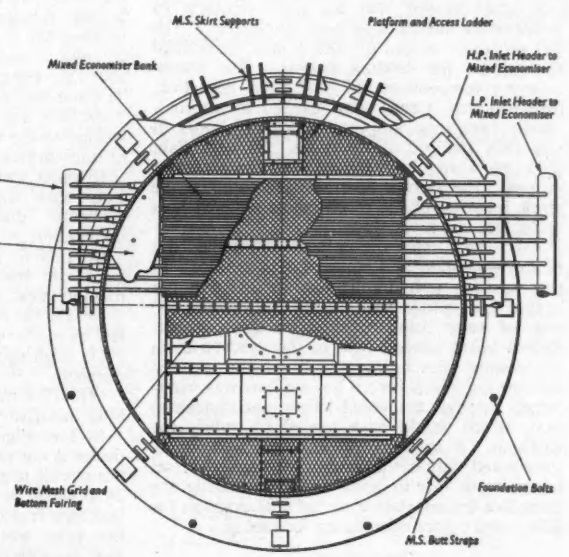
SECTIONAL PLAN LOOKING IN DIRECTION OF ARROW 'A' UP TO 'BB'.


L.P. Drum Cyclones (Internal pipes and nozzles etc. omitted for clarity)
L.P. Drum Supports
H.P., H.T. Economiser Bank and Outlet Tubes
Platform and Access Ladder
Baffle Plate
L.P. Superheater Inlet Header
L.P. Superheater Outlet Header
L.P. Superheater Bank
Platform and Access Ladder

SECTIONAL PLAN LOOKING IN DIRECTION OF ARROW 'CC' UP TO 'DD'.


Platform and Access Ladder
H.P. Boiler Side Plating Upper Bank
H.P. Boiler Lower Bank Inlet Header
H.P. Boiler Lower Bank Inlet Header
H.P. Inlet Header to Mixed Economiser
Baffle Plates
H.P. Boiler Lower Bank
H.P. Boiler Upper Bank
H.P. Boiler Upper and Lower Bank Connecting Tubes
H.P. Boiler Upper and Lower Bank Connecting Tubes
H.P. Boiler Side Plating Lower Bank

SECTIONAL PLAN LOOKING IN DIRECTION OF ARROW 'BB' UP TO 'CC'.


M.S. Skirt Supports
Platform and Access Ladder
Mixed Economiser Bank
H.P. Inlet Header to Mixed Economiser
L.P. Inlet Header to Mixed Economiser
Wire Mesh Grid and Bottom Fairing
Foundation Bolts
M.S. Butt Straps

SECTIONAL PLAN LOOKING IN DIRECTION OF ARROW 'EE'

Fig. 4—Cross-sections through heat exchangers

welding was downhand using E.G. "Unitrode" low hydrogen content electrodes with d.c. power, the sections being mounted on horizontal bogies in the site workshop, a proportion being power driven to enable the sections to be rotated.

As the work progressed the 100 hours initially taken to weld each circumferential seam was reduced as experience was gained in fabrication, and a changeover to double "V" preparation was made with a resultant saving in time of thirty-five hours per seam.

It was decided that stress relieving of all site welds made on the vessel should be undertaken, although the diameter/thickness ratio of the vessel was very high and lay outside previous experience. Gas heating was rejected on the grounds of uneven heating, and finally it was decided to use high-frequency electrical heating. The plant for this purpose was developed in conjunction with the Electric Furnace Construction Company, Ltd., and consisted of a 200kW totally enclosed, water-cooled, motor-alternator set, generating 2·5 kc/s.

The lagging used to cover the conductors, apart from economising in the amount of heat

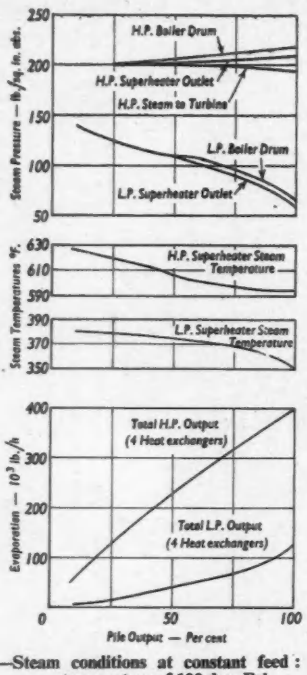


Fig. 5—Steam conditions at constant feed: water temperature of 100 deg. Fah.

necessary to bring the weld up to the required temperature, also slowed down the heat dissipation and ensured that the axial gradient of temperature distribution was minimised. The full generator output of 200kW was maintained throughout the heating period. The stress-relieving temperature of 1148–1166 deg. Fah. (620–630 deg. Cent.) was reached in approximately three hours and then held for 1½ hours. It was then reduced at a rate of 360 deg. Fah. (200 deg. Cent.) hour by reducing the generator output. The average time taken to complete the stress relieving of the seven seams on each heat exchanger was seven days.

After stress relief the vessels were hauled out of the workshop and jacked on to cradles. In this position a hydraulic test to 237·5 lb per square inch gauge was carried out, about 400 tons of water being required for this purpose. Before being handed over to the erection team the vessels were thoroughly dried and cleaned out, during which time a hot air flow was maintained through the vessel to prevent condensation, which would have tended to nullify the cleaning. A quantity of silica gel was finally distributed within the temporarily sealed vessel to maintain this in good condition during the period of transportation to the final position for lifting and before opening up for tubing.

Tube System

To reduce the possibility of inter-leakage between the steam or water and the CO_2 coolant, it was considered advantageous to keep all sections of the plant, other than the heat transfer surfaces, outside the gas circuit. This not only reduced the possibility of leakage, but, by suitable design, made it feasible to detect and make inoperative a leaking element without entering the gas system. Furthermore, the multi-loop type of element, with its inherent flexibility, seemed admirably suited for minimising any stresses set up in the tubes due to thermal expansion.

The requirement of maintaining the plant in a leaktight condition throughout its life, together with the requirement of minimum outage, influenced the disposition of the heat-transfer surfaces. It was decided also to adopt a forced circulation system on the water side once this enabled a packed arrangement of heating surface, divided into relatively small units, to be installed. The horizontal arrangement of the tubes reduced the overall height. The final arrangement of tubes selected is shown in Figs. 3 and 4.

Where it was necessary to take the tube elements through the pressure vessel for external connection, thermal sleeves were provided (see Fig. 6). In addition to their usual function of providing a gradual transition from thin tube to relatively thick shell, to minimise stress concentrations, they enabled all site welds to be made outside the vessel away from the clean area required for tubing out. The design was so arranged that the tube elements should have at least one end connected into a header, so that once permanent instrumentation had indicated a leak, the faulty tube (or tubes) could be detected by draining the water from the heat exchanger while maintaining the CO_2 pressure at 100 lb per square inch gauge and probing with a CO_2 leak detector along the headers. Once a leaking tube has been detected it is possible to cut a piece of tube from the connection between the pressure shell and the header, and plug the ends, thus isolating the offending tube from both the gas and the steam circuits. Sufficient space was made available between the banks to enable an element to be removed and, in addition, a vertical passage was provided between all tube banks to allow any bank of elements to be removed and replaced without disturbing the other banks (Fig. 3).

Tube and Element Manufacture.—Solid drawn, seamless tubing and electrical resistance welded (E.R.W.) tubing were considered, the latter being selected for installation because of its immediate availability in the large quantities required. With the exception of the economisers the tube elements were made up from straight lengths of studded tube bent and welded together to form an element. On the economiser sections, however, it was not possible to form elements by bending straight lengths of studded tube, as each separate length was staggered one tube diameter from the one above. The economisers, therefore, were made up of straight studded lengths formed into a continuous element by welding 180 deg. bends to each end. The length of tube in each element, with the exception of the l.p. superheater, is approximately 250ft. The number of studs per bank varies between 2,000,000 and 3,250,000. These were flash welded to the tube two at a time using batteries of semi-automatic machines.

In order to avoid leaking tubes the following tests were specified for the tubes and tube elements during manufacture and after installation :—

(*a*) 1000 lb per square inch gauge hydraulic tests on the tubes before acceptance for manipulation.

(*b*) 750 lb per square inch gauge hydraulic test on each completed tube element.

(*c*) High vacuum test on each completed tube element.

(*d*) 475 lb per square inch gauge hydraulic test after installation on site.

In the original consideration of the reactor design it was decided to install drying plant in the gas circuit which would be capable of removing 2½ lb water per hour. It was estimated that the leak rate from each of the 1000 elements to give this value was equivalent to 2 lusecs.§ It was also considered that under certain conditions, this leakage rate might increase by a factor of 100. The permissible leakage rate for acceptance of the tube elements was, therefore, fixed at 2 clusecs (1 clusec = 1/100 of a lusec).

The detection of such small leaks had not been attempted before on a production scale. Vacuum technique was used, the flow sheet for the test apparatus being shown in Fig. 7. The elements were exhausted with a roughing pump to a vacuum of 25 microns to 30 microns and then enough switched to the backing pump. When a high vacuum had been attained the diffusion pumps were brought into line and the system stabilised. When stabilised, the instruments were calibrated against a standard 2 clusec leak supplied with hydrogen. This artificial leak was then isolated, the tube element under test enveloped in a bag which was filled with hydrogen and the tube element tested for leaks. It was fortunate that a stable 2 clusec leak had just been developed by the Authority for another purpose. The apparatus was installed at the manufacturer's works and, on average, twelve elements a day were tested.

In fitting out the heat exchangers, considerable emphasis was placed on achieving cleanliness to a standard not met with in normal engineering practice. All possible steps were taken to prevent loose scale, rust or other foreign matter finding its way into the CO_2 coolant system.

Circulating Pumps and Fittings

Having adopted forced circulation for the evaporative sections of the heat exchangers it was decided to provide two pumps for both the h.p. and l.p. systems; one to act as stand-by. To gain operational experience two

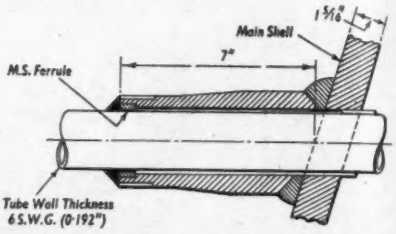


Fig. 6—Thermal sleeve for passing tube through shell

different types of pump were used. That chosen for the normal duty was a submersible type, and that for standby duty a horizontal pump fitted with water-cooled glands.

Two drums were provided on each heat exchanger, one for the h.p. steam and one for the l.p. steam, both mounted on the vessel itself

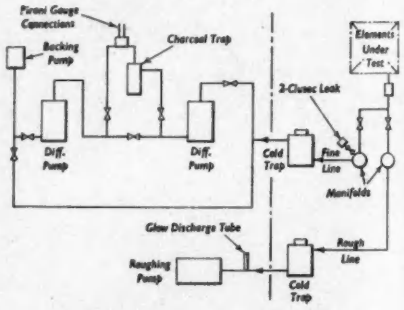


Fig. 7—Leak test flow sheet

as shown in Fig. 3. The drums were provided with cyclone steam separators and scrubbers of the type usually applied in orthodox boiler practice. Steam heaters were incorporated for warming-up should this be required.

The safety valves on the steam side were fitted on the drums only and the settings were related not only to the normal operation of the plant but also when operating on the dump condenser. The h.p. control valves on the dump system are set to lift at 195 lb per square inch gauge and are fully open at 210 lb per square inch gauge. The difference between the latter figure and the lowest drum setting is 30 lb per square inch gauge, but this margin may be increased later. Three safety

§ 1 lusec is a leakage rate which causes a pressure rise of 1 micron/sec when leaking into a volume of 1 litre.

valves were fitted on the h.p. system and these are set at 240 lb, 245 lb and 250 lb per square inch gauge. On the l.p. drum, two safety valves were adequate at settings of 170 lb and 180 lb per square inch gauge respectively. The lower setting of the l.p. valves helps to protect the reactor against the effect of the higher return gas temperatures.

The choice of feed regulators presented some difficulty, particularly as the plant is out of doors and unprotected. It was considered that a float-type regulator offered the best solution for the h.p. system, working in conjunction with a float-gear unit and a separate check valve. The higher pressure difference between the feed water and steam pressure on the l.p. system necessitated the use of a float-gear unit alone. Electrical trace heating was used to prevent freezing on the down pipe from the h.p. float gear to the feed control valve.

Instrumentation

In view of the anticipated steady operating conditions of the plant over long periods, and the relatively few controls required on the heat exchangers, instrumentation was kept to a minimum. Consideration was given, however, to the need for special instrumentation, bearing in mind that the plant was a prototype. A small panel was installed in the pump house below each heat exchanger to indicate the following : (*a*) h.p. and l.p. superheater outlet pressures ; (*b*) main and auxiliary feed line pressures ; (*c*) h.p. and l.p. drum water levels ; (*d*) differential pressure across each pair of water circulating pumps (only one pump on each l.p. and h.p. system is normally in operation) ; (*e*) gas temperature of the CO_2 as it passes each tube bank (on one heat exchanger only).

In addition to the gauge glasses fitted to the drums, bi-colour water level indication was provided in each pump house.

A series of alarms was incorporated in an extension to the associated main CO_2 circulator control panels situated in the circulator houses, as this was the nearest permanently manned position within easy reach of the pump houses. It was considered necessary to provide the following alarms : (i) high and low level water in each of the h.p. and l.p. drums ; (ii) loss of feed pressure in whichever main is being used ; (iii) circulating pump failure, whether this occurs through tripping out of the pump motor starter, or, as the result of excessive temperature rise in the pumps.

Although is was expected that prompt action would be taken by the circulator-house personnel on indication of a fault, it was decided also to present the alarms in grouped form in the reactor control room where supervisory control is centred.

Since measuring devices had to be included in the steam mains to obtain flows, pressures, and temperatures for the purpose of heat balance on the plant and for calibration of the gas-flow venturis at the reactor outlet ducts, it was considered reasonable to provide permanent instrumentation for these measurements. Provision was also made to enable test measurements of temperature and flow of the feed water to be taken in the individual branches to the heat exchangers by the inclusion of thermometer pockets and spacers in the mains into which standard orifice carriers and plates would be fitted.

The possibility of carry-over of water from the drums to the superheaters, and subsequently from the superheaters to the turbines is checked at frequent intervals by determining the conductivity readings obtained from portable equipment used initially for continuous sampling between the drums and the superheaters. This consists of normal water-purity measuring equipment with dual range recorders, and a degassing unit to condense the steam and drive off the non-condensable gases. If gases affecting the conductivity are completely removed the conductivity of the condensate is proportional to the concentration of dissolved solids in the sample. This conductivity can be converted to a percentage carry-over by comparison with the conductivity of the drum water. The maximum carry-over was specified at 0·5 per cent.

Particular attention was paid to the purity of the feed water. It was considered advisable to maintain continuous observation for leakage of raw water into the cooling water system in the turbine house, which could introduce dissolved salts into the feed water system, and increase the risk of corrosion and solid deposits in the heat exchangers. Water-purity indicators were provided, therefore, in the condensate lines after each turbine and dump condenser. While a considerable amount of care had been taken in the design of the steam plant to prevent the ingress of oxygen into the system, oxygen detection equipment was provided. The specified maximum oxygen content is 0·005 c.c. per litre, and recording equipment has been provided in each feed system to analyse the condensate both before and after the de-aerators in the turbine house.

Since the gas in the reactor and heat exchangers is maintained at a pressure of 115 lb per square inch absolute and the l.p. steam system is normally operating in the region of 63 lb per square inch absolute it would be possible should a tube leak occur for the CO_2 to enter the l.p. steam system ; accordingly one set of CO_2 detection equipment was installed in each l.p. steam main. This equipment consists of a chamber containing soda asbestos through which air is passed to remove the normal CO_2 content. The air is then passed through a chamber, which contains the l.p. condensate, and collects in its passage any CO_2 present in it. The presence of CO_2 in the air after its passage through the condensate is detected by infra-red gas analyser.

A faulty tube on the h.p. system operating at 210 lb per square inch absolute could result in steam or water leaking into the CO_2 and it was considered essential to be able to detect such leakage. An infra-red gas analyser was, therefore, installed to sample continuously the gas in the heat exchanger.

To minimise the risk of tube failure, water treatment plant was installed. Water, which is drawn from Lake Wastwater, is freed from its inorganic impurities in a mixed bed ion exchange demineralisation plant, and the make-up is admitted to the system through a de-aerator of the pressure type. Pending operating experience, the total dissolved solids in the drum water were fixed at 1500 p.p.m. and orthodox blow down equipment is installed to implement this.

Maintenance

It is expected that internal examination of the heat-exchanger vessels will be possible, although some activity from the active isotopes of carbon and argon or trace amounts of fission products may be encountered. Special precautions would have to be taken, however, in the unlikely event of fission products becoming lodged in the heat exchanger.

Access into the heat exchangers is gained through manholes in the top gas ducts connecting the heat exchangers to the reactor. Access doors are provided between each bank in the vessel, on all four sides of the rectangular pattern of the tube banks (Fig. 3).

A limited amount of examination of the plant can be accomplished by the use of an "Introscope," obviating the necessity of entering the vessel. These are particularly applicable in the examination of the headers and between the tube banks. Examination holes have been left in the ends of the headers through which the "Introscopes" can be inserted. This will allow visual examination of the internal surfaces of the headers, the restrictor nozzles and some portion of the tubes, the latter giving an indication of the condition of the remainder of the tubes. In the case of the external surfaces of the tube elements, conveniently positioned holes, normally blanked off, are provided around the circumference of the vessel, to allow an "Introscope" to be inserted between the banks of elements. This enables the top and bottom tube of each element to be examined visually.

Research on Automobile Stability

No. III—(*Continued from page 808, December 7*)

The Flight Research Department of the Cornell Aeronautical Laboratory has for many years been engaged on the performance of full-scale research on the stability and control of aircraft. A development contract was undertaken for General Motors Research Staff to secure a better understanding of the directional stability and control of automobiles. The lack of flat-road tyre data of a form and completeness suitable for stability and control analyses led to the development of a six-component tyre testing apparatus under a contract with the U.S.A.F.

IN "Design Implications of a General Theory of Automobile Stability and Control," by Whitcomb and Milliken,* further simplifying assumptions beyond those of Segel's paper are made in the dynamic system representing the car by reducing it to a model having only two degrees of freedom, yawing and sideslip. In this way the existing wide knowledge of second order dynamic system behaviour can be used, and a simpler and more vivid picture obtained of the essential vehicle response characteristics, although limited to cars having restricted roll movement.

This paper is of the same pattern as Segel's and develops the steady and transient response of the "two degree of freedom" vehicle by use of the stability derivative notation. It will be sufficient here to list the developed response equations and briefly remark on their significance, and whilst sufficient data is included for the reader to make practical use of the results, it is recommended that a full study of the original paper be made.

The same assumptions of linearity, small angles and amplitudes will be made as in Segel's paper and since the roll has been eliminated the car may be assumed to be of no width with the wheels on the centre line.

Equations of Motion.—The kinematics of the vehicle turning motion is shown in Fig. 11. The equations of motion can be written in terms of stability-derivative notation as

$$Y_\beta\beta + Y_r r + Y_\delta\delta = M(\dot{v} + V_r) \quad . \quad . \quad (77)$$

$$N_\beta\beta + N_r r + N_\delta\delta = I_z\dot{r} \quad . \quad . \quad . \quad . \quad . \quad (78)$$

These are the equations of motion of the "two

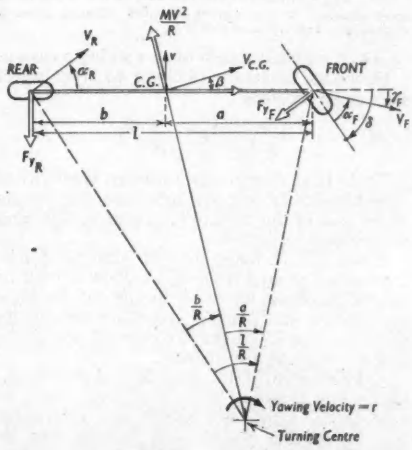


Fig. 11—Kinematics of the turning motion

New notation.

D, E—Coefficients of stability quartic.
N.S.P.—Neutral steer point.
T—Period, seconds.
t—Time, seconds.
ζ—Damping ratio.
ψ—Vehicle heading angle.

Subscripts :

F—Front.
R—Rear.
y—Lateral.
z—Vertical.

* "Research in Automobile Stability and Control and in Tyre Performance," I.Mech.E., Nov. 13, 1956.

degree of freedom" vehicle and their solution will yield the response characteristics of such a machine.

Steady State Response and Discussion of the Characteristics.—The steady state response is the culmination of the transient condition and represents the static behaviour of the car. It therefore determines the static or steady state stability and control characteristics.

Since in the steady state $\dot{r}=0$ and $\dot{v}=0$, the substitution of V/R for r will give the equations of motion the following form :

$$Y_\beta\beta+(VY_r-MV^2)1/R=-Y_\delta\delta \quad . \quad (79)$$

$$N_\beta\beta+VN_r(1/R)=-N_\delta\delta \quad . \quad (80)$$

The solution of these for the steady state in terms of $1/R$ yields the steady state curvature response in the form

$$\frac{1/R}{\delta}\Big)_{ss}=\frac{Y_\beta N_\delta-N_\beta Y_\delta}{N_\beta(VY_r-MV^2)-VY_\beta N_r} \quad . \quad (81)$$

This can be reduced to

$$\frac{1/R}{\delta}\Big)_{ss}=\frac{1/l}{1+KV^2} \quad . \quad . \quad . \quad . \quad (86)$$

which is a familiar form, where it can be shown that

$$K=\frac{M}{lY_\delta}\left(\frac{\text{Static margin}}{\text{Neutral steer point}}\right) \quad . \quad (89)$$

Alternately

$$K=\frac{M}{l^2}\left[\frac{a}{C_R}-\frac{b}{C_F}\right].$$

K is known as the stability factor and uniquely determines the manner in which the curvature response varies with speed. For negative values of K the vehicle becomes unstable when

$$V=\sqrt{-\frac{1}{K}}.$$

Whitcomb and Milliken now derive the remainder of the steady state response equations, but it is noted that the term $N_\beta Y_r-N_\beta MV-Y_\beta N_r$ constantly recurs in the denominators of all the derived functions. In order to present the response functions in a more concise form, which is perhaps easier to assimilate, they may then be tabulated and grouped in the form shown in Table II, if $N_\beta Y_r-N_\beta MV-Y_\beta N_r$ is expressed as

TABLE II—*Response Functions*

Type of response (steady state)	Inputs		
	Front wheel steer angle δ	Side force F_s	External yaw moments N
Curvature $=\frac{1}{R}$	$\frac{1}{QV}(Y_\beta N_\delta-N_\beta Y_\delta)$	$\frac{1}{QV}(-N_\beta)$	$\frac{1}{QV}(Y_\beta)$
Yawing velocity $=r$	$\frac{1}{Q}(Y_\beta N_\delta-N_\beta Y_\delta)$	$\frac{1}{Q}(-N_\beta)$	$\frac{1}{Q}(Y_\beta)$
Acceleration $=\frac{V^2}{R}$	$\frac{V}{Q}(Y_\beta N_\delta-N_\beta Y_\delta)$	$\frac{V}{Q}(-N_\beta)$	$\frac{V}{Q}(Y_\beta)$
Sideslip $=\beta$	$\frac{1}{Q}\{Y\ N_r-N_\delta(Y_r-MV)\}$	$\frac{1}{Q}(N_r)$	$\frac{1}{Q}-(Y_r-MV)$

N.B. $Q_{K=0}$ contains a speed sensitivity $\cong 1/V$, therefore the speed sensitivity of the response functions indicated above is misleading. This is discussed later.

Q, which may be thought of as a spring constant.

Hence the curvature response to front wheel steer angle becomes

$$\frac{1/R}{\delta}\Big)_{ss}=\frac{Y_\beta N_\delta-N_\beta Y_\delta}{QV}.$$

Table II at once shows a marked similarity of form between the response equations, particularly in the case of the curvature, yawing velocity and acceleration responses.

It will also be noted that the response due to front wheel steered angle δ is a control input or desired response, whilst those due to side force and external yaw moment constitute the stability responses and in general are external and therefore undesirable disturbances.

A knowledge of the vehicle and tyre parameters will enable K to be evaluated readily in accordance with (89), whilst the derivatives Y_β, Y_r, Y_δ and N_β, N_r and N_δ may then be evaluated easily in terms of the same parameters in accordance with Segel's dimensional equations, omitting the derivatives applicable to the rolling degree of freedom.

A complete set of steady state response functions is now available, in stability derivative form. A study of these individually yields certain significant and some interesting conclusions regarding the physical determinants of response behaviour.

(1) *Curvature Response to Steered Angle.*—It is shown that if $N_\beta=0$, i.e. when the static margin is zero or when $K=0$, then

$$\frac{1/R}{\delta}\Big)_{ss}=\frac{Y_\beta N_\delta}{-VY_\beta N_r}=-\frac{1}{V}\left(\frac{N_\delta}{N_r}\right) \quad . \quad (105)$$

The curvature response thus depends essentially on the ratio of steering control sensitivity to yaw damping. Since N_r varies inversely with speed, the response will be constant for all speeds in this particular case.

Further, from consideration of $N_\beta Y_\delta$ the neglected part of the numerator term, the decrease of curvature response when N_β is positive, or increase when N_β is negative, is seen to be caused directly by the moment contribution of N_β.

(2) *Physical Significance of the Critical Speed.*—In terms of stability derivatives a physical significance of the critical speed $V=\sqrt{-1/K}$ can be seen. The response is infinite if the complete denominator of any of the response equations is zero or if $N_\beta Y_r-N_\beta MV-Y_\beta N_r=0$ or $Q=0$.

This critical speed is shown to exist only if N_β is negative. In other words, if the static margin or K is negative.

The moment due to N_β is attempting to increase curvature, while that due to N_r is attempting to prevent this increase. At the critical speed these moments are equal and opposite and any disturbance results in a condition where equilibrium cannot be maintained.

(3) *Yaw Velocity Response to Steered Angle and*

(4) *Acceleration Response to Steered Angle.*—Since

$$\frac{r}{\delta}\Big)_{ss}=V\left(\frac{1/R}{\delta}\right)_{ss} \quad . \quad . \quad (106)$$

therefore from (105) when $N_\beta=0$ (or $K=0$)

$$\frac{r}{\delta}\Big)_{ss}=-\frac{N_\delta}{N_r} \quad . \quad . \quad . \quad . \quad (107)$$

and likewise

$$\frac{V^2/R}{\delta}\Big)_{ss}=-V\left(\frac{N_\delta}{N_r}\right) \quad . \quad . \quad (108)$$

Since N_r is inversely proportional to speed, the yawing velocity response increases linearly with speed and the acceleration response increases as the square of the speed for zero static margin.

(5) *Physical Significance of the Ackermann Angle* $\sim l/R$.—If (107) is further expanded it can be demonstrated that

$$N_r\,.\,r=-N_\delta\frac{l}{R} \quad . \quad . \quad . \quad . \quad (111)$$

$+N_r r$ is the yawing moment due to damping in yaw and equals the moment $-N_\delta l/R$. This implies that l/R is a steered angle. The steady state steering angle when $K=0$ is known to be l/R or the Ackermann angle. The real significance of the Ackermann angle is now apparent, for it is the steering angle required to counteract the yaw damping moment. Any increase or decrease of steering angle from this value will be the result of additional moments as a result of finite values of N_β.

The solutions have so far revealed that the turning response of the car is primarily determined by the yaw damping constant and that the Ackermann steering angle is the control input required to overcome this damping.

(6) *Sideslip Response to Steered Angle.*—From the sideslip response function it can be shown that $N_\delta MV$ is by far the most significant numerator term and that $Y_\beta N_r$ is the most significant denominator term. Hence :

$$\frac{\beta}{\delta}\Big)_{ss}\cong-\frac{N_\delta MV}{Y_\beta N_r} \quad . \quad . \quad . \quad . \quad (112)$$

Comparing (112) with (108) shows that

$$\frac{\beta}{\delta}\Big)_{ss}=\frac{M}{Y_\beta}\left(\frac{V^2/R}{\delta}\right)_{ss} \quad . \quad . \quad (113)$$

This conclusion is very logical and obvious because $M\times V^2/R=$Centrifugal Force$=$Force to be reacted by the tyres$=-C=Y_\beta$. Cars of comparable sideslip response will therefore have the same value of M/Y_β.

(7) *Responses to Externally Applied Side Forces and Yawing Moments.*—These responses are very significant since they show how the car responds to cambering roads and wind gusts. Since a wind gust will generally apply a side force at a point not coincident with the c.g. a study of the combined responses will permit some preliminary conclusions of gust behaviour.

Considering the side force response first and approximating the denominator by $-Y_\beta N_r$ as before

$$\frac{1/R}{F_y}\Big)_{ss}\cong\frac{N_\beta}{VY_\beta N_r}=\frac{1}{V}\left(\frac{N_\beta/Y_\beta}{N_r}\right)=-\frac{l}{V}\left(\frac{\text{Static margin}}{N_r}\right) \quad . \quad . \quad . \quad . \quad . \quad (114)$$

and

$$\frac{r}{F_y}\Big)_{ss}\cong\frac{N_\beta}{Y_\beta N_r}=-l\left(\frac{\text{Static margin}}{N_r}\right) \quad . \quad . \quad (115)$$

and

$$\frac{V^2/R}{F_y}\Big)_{ss}\cong-Vl\left(\frac{\text{Static margin}}{N_r}\right) \quad . \quad . \quad . \quad . \quad (116)$$

and

$$\frac{\beta}{F_y}\Big)_{ss}\cong-\frac{1}{Y_\beta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (117)$$

and further since $v=V.\beta$.

the lateral velocity response to sideslip

$$\frac{v}{F_y}\Big)_{ss}=V\left(\frac{\beta}{F_y}\right)_{ss}=\frac{-V}{Y_\beta} \quad . \quad (118)$$

It can be seen that the curvature, yaw velocity and acceleration responses vary directly with the static margin, that is, the response is positive $\sim$zero$\sim$negative when the static margin is positive$\sim$zero$\sim$negative respectively. The speed sensitivities of these three responses are indicated by N_r which is inversely proportional to speed. Hence, the curvature response is independent of speed, while the yaw velocity and acceleration responses are proportional to speed and the square of the speed respectively.

The sideslip response to side force is independent of both static margin and speed, there being a sideslip response when the static margin is zero.

The lateral velocity response to side force is proportional to speed and is very important for a fast car. Clearly increasing the value of Y_β is the way to minimise lateral velocity and hence the displacement in unit time.

Now consider the yawing moment responses. Approximating again for the denominator by $-Y_\beta N_r$.

$$\frac{1/R}{N}\Big)_{ss}\cong-\frac{1}{VN_r} \quad . \quad . \quad . \quad . \quad (119)$$

and

$$\frac{r}{N}\Big)_{ss}\cong-\frac{1}{N_r} \quad . \quad . \quad . \quad . \quad (120)$$

and

$$\frac{V^2/R}{N}\Big)_{ss}\cong-\frac{V}{N_r} \quad . \quad . \quad . \quad . \quad (121)$$

These values are exact for $N_\beta=0$. And, since Y_r is generally a small quantity, the sideslip response is

$$\frac{\beta}{N}\Big)_{ss}\cong-\frac{MV}{Y_\beta N_r}=\frac{M}{Y_\beta}\left(\frac{V^2/R}{N}\right)_{ss} \quad . \quad . \quad (122)$$

The curvature, yawing velocity and acceleration responses again show the importance of yaw damping in determining the response. Speed sensitivity is comparable with the case of steer angle responses, which is not surprising since steering applies a yawing moment equal to $N_\delta\delta$.

In general, for conventional cars, wind gusts apply a side force and moment consistent with a centre of pressure forward of the centre of gravity. That is, the response is that due to $+F_y$ plus that due to $+N$. The total effect of this on the two degree of freedom vehicle is shown below in Table III.

TABLE III—*Steady State Response to Wind Gusts Acting at a Forward Centre of Pressure*

Stability of vehicle	Inputs	
	Side force alone at c.g. $+Fy$ (from left say)	Yawing moment alone $+N$ (due to a side force from the left acting forward of the c.g.)
Car with $N_\beta=0$ or $K=0$ or $SM=0$ (Neutral steer)	Sideslip to right (from direct force) zero yaw (because N.S.P. coincides with c.g.)	Turn to right (from direct moment)
Car with $N_\beta+ve$ or $K+ve$ or $SM+ve$ (Understeer)	Sideslip to right (from direct force) +slight turn to right (due to moment arm of N.S.P. aft of c.g.)	Turn to right (from direct moment) −slight turn to left (from the stabilising moment of a $+re\ N_\beta$ in the above steady right turn)
Car with $N_\beta-ve$ or $K-ve$ or $SM-ve$ (Oversteer)	Sideslip to right (from direct force) −slight turn to left (due to moment arm of N.S.P. forward of c.g.)	Turn to right (from direct moment) +slight turn to right (from the de-stabilising moment of a $-re\ N_\beta$ in the above steady right turn)

From examination of Table III the following interesting conclusions can be drawn.

(*a*) The total response to wind gusts is dependent on the relative numerical values of F_y, N and N_β.

(*b*) The car with $N_\beta-ve$ is not necessarily the least disturbed by gusts in the steady state, as it would appear at first, again because of (*a*).

(*c*) The most effective way of reducing the total disturbance is to alter the body design configuration so that N is reduced.

(*d*) As first pointed out by Kamm, the responses tend to cancel one another out when the centre of pressure is just behind the centre of gravity, combined with a suitable $+ve$ value of N_β.

Transient Response and Discussion of the Characteristics.—The approach made by Whitcomb and Milliken is first to study two separate "single degrees of freedom" motions, sideslip without yaw and yaw without sideslip, in order to identify the governing parameters and to obtain a keener appreciation of the characteristics. They then study the "two degree of freedom" car with sideslip and yaw, but neglecting roll, and compare the motions.

Sideslip Response to a Side Force, Zero Yawing.—The time solution for the sideslip velocity as a function of F_y is derived as

$$\frac{v}{F_y}=-\frac{V}{Y_\beta}\left(1-\frac{Y_\beta}{e^{MVt}}\right) \quad . \quad . \quad . \quad . \quad (125)$$

This response is exponential in character, typical of a first-order dynamic system, and is convergent since Y_β is a negative quantity. The response magnitude increases with speed. For large values of time, the exponential term approaches zero and the equation reduces to the steady state response given by (118).

From (125) the following relationships are derived.

(i) The response time for the car to acquire approximately 63 per cent, or $1-1/e$, of its final value, commonly called the "response time," is

$$t_{1/e}=-\frac{MV}{Y_\beta} \quad . \quad . \quad . \quad . \quad . \quad (126)$$

(ii) Differentiation of (125),

$$\frac{\dot{v}}{F_y}=\frac{1}{M}e^{\frac{Y_\beta}{MV}t} \quad . \quad . \quad . \quad . \quad (127)$$

shows that the initial rate of change of sideslip velocity depends on the vehicle mass and does not vary with speed. Thus, the increase in vehicle response time with speed is the result of the increase in the steady state response.

(iii) The lateral displacement of the car y may be found by integrating (125)

$$\frac{y}{F_y}=\int\left(\frac{v}{F_y}\right)dt=-\frac{V}{Y_\beta}\left[t+\frac{MV}{Y_\beta}\left(1-\frac{Y_\beta}{e^{MVt}}\right)\right] \quad (128)$$

from this the displacement in terms of road camber change is easily derived, since $F_y-W\sin\phi \simeq W\phi$ for small angles, so that

$$\frac{y}{\phi}=-\frac{gMV}{Y_\beta}\left[t+\frac{MV}{Y_\beta}\left(1-e\frac{Y_\beta}{MVt}\right)\right] \quad . \quad (129)$$

From this it may be seen that the lateral displacement depends directly on the weight of the vehicle, and that in a given time it depends both on the steady state velocity and on the time constant. Typical time constants are comparable with the driver's reaction time and shorter, therefore, the response will be minimised if the steady state lateral velocity is minimised. Thus, a high value of the tyre cornering stiffness is desirable in order that M/Y_β may be small.

The foregoing conclusions are significant for the behaviour of the car on cambered roads and in wind gusts, both of these being undesirable disturbances. The dependence of lateral displacement on speed also suggests a "critical" speed at which the lateral divergence of the car within the driver's response period plus the vehicle response period to corrective action may become excessively large.

Yawing Response to Steer Angle, Zero Sideslip.—A summary of the single degree of freedom transient motions includes the following conclusions :—

(*a*) The yawing motion is typical of a second order dynamic system, consisting of a spring, mass and viscous damper.

(*b*) The motion is convergent if N_β is positive and divergent if negative.

(*c*) The motion when convergent will be exponential at low speeds and for small positive values of N_β and oscillatory at high speeds, and for large positive values of N_β.

(*d*) The response time depends primarily upon the ratio of moment of inertia to yaw damping, and increases with speed.

(*e*) The natural frequency is determined by the ratio of N_β to the moment of inertia, and is independent of speed.

(*f*) The damping ratio is a function of yaw damping, moment of inertia and N_β, and will decrease for increases in speed and static margin.

(*g*) The damping ratio is equal to 1·0 at the transition speed, and is greater than 1·0 for lower speeds and less than 1·0 at higher speeds.

"Two Degree of Freedom" Transient Response.—The general equations of motion (77) and (78) may be solved to yield the following relationships for $r(s)$ and $\beta(s)$:—

$$\left[s^2-\left(\frac{Y_\beta}{MV}+\frac{N_r}{I_z}\right)s+\frac{N_\beta}{I_z}-\frac{Y_rN_\beta}{MVI_z}+\frac{Y_\beta N_r}{MVI_z}\right]r(s)$$
$$=\left(\frac{N_\beta Y_\delta-Y_\beta N_\delta}{MVI_z}\right)\delta(s)+\frac{N_\delta}{I_z}s\delta(s) \quad . \quad (152)$$

and

$$\left[s^2-\left(\frac{Y_\beta}{MV}+\frac{N_r}{I_z}\right)s+\frac{N_\beta}{I_z}-\frac{Y_rN_\beta}{MVI_z}+\frac{Y_\beta N_r}{MVI_z}\right]\beta(s)$$
$$=\left(\frac{Y_rN_\delta-Y_\delta N_r}{MVI_z}-\frac{N_\delta}{I_z}\right)\delta(s)+\left(\frac{Y_\delta}{MV}\right)s\delta(s) \quad . \quad (153)$$

The terms on the left-hand side of equations (152) and (153) are identical and are the characteristic equation of the car. The spring and damping constants, and hence the frequencies and damping ratios of the motion in terms of either variable will therefore be identical.

The terms on the right-hand side of equations (152) and (153) are different and signify that the amplitudes of the two responses will differ. The response amplitude depends on steering rate as well as the magnitude of steering input, and is denoted by the presence of the terms $(N_\delta/I_z)s\delta(s)$ and $(Y_\delta/MV)s\delta(s)$.

The following are also derived from the solution of the general equations of motion.

Damping Coefficient

$$=-(I_zY_\beta+MVN_r) \quad . \quad . \quad . \quad (154)$$

Spring Constant

$$=-N_\beta Y_r+N_\beta MV+Y_\beta N_r \quad . \quad . \quad (155)$$

[*Note.*—(155)$=-Q$, the common denominator term in the steady state response discussion.]

The characteristic equation may now be examined to determine conditions for vehicle stability, natural frequency, damping ratio and response time.

The conditions for dynamic stability are found to be the same as for steady state analysis, and the critical value of N_β given by

$$N_\beta<-\frac{Y_\beta N_r}{Y_r+MV} \quad . \quad . \quad . \quad (160)$$

Equation (160) implies the stable operation of a vehicle of negative static margin up to critical speed.

The response derived from the equations of motion can be either experimental or oscillatory, and the condition for non-oscillatory behaviour is given by

$$S.M.<-\frac{N_r^2}{4lI_zY_\beta}+\frac{N_r}{2lMV}-\frac{Y_\beta I_z}{4l(MV)^2} \quad . \quad (164)$$

The vehicle will, therefore, have an oscillatory motion for any positive static margin and an exponential response for negative static margins.

The natural frequency of oscillatory motion is given by

$$\omega_n=\sqrt{\frac{N_\beta}{I_z}-\frac{Y_rN_\beta}{MVI_z}+\frac{Y_\beta N_r}{MVI_z}} \quad . \quad . \quad (169)$$

This natural frequency is a function of speed and static margin, and will decrease with increases in speed, but will increase with static margin. The frequency value will always be greater than $\sqrt{N_\beta/I_z}$ but will approach it at high speeds.

The damping ratio of this oscillatory motion is given by

$$\zeta=\frac{-\left(\frac{Y_\beta}{MV}+\frac{N_r}{I_z}\right)}{2\cdot\omega_n} \quad . \quad . \quad . \quad (172)$$

The motion is theoretically oscillatory for damping ratios less than 1·0, but will not significantly overshoot the steady state value until the damping ratio is less than 0·7. This implies that the damping ratio is unity when the static margin is zero from equation (164).

The response times of the car can be derived from the left-hand side of equations (152) and (153), giving the quadratic solution

$$t=\frac{1}{\frac{D}{2}\pm\sqrt{\frac{D^2}{4}-E}} \quad . \quad . \quad . \quad . \quad (165)$$

where

$$D=-\left(\frac{Y_\beta}{MV}+\frac{N_r}{I_z}\right) \quad . \quad . \quad . \quad (157)$$

and

$$E=\frac{N_\beta}{I_z}-\frac{Y_rN_\beta}{MVI_z}+\frac{Y_\beta N_r}{MVI_z} \quad . \quad . \quad (158)$$

For oscillatory response,

$$t=\frac{2}{D}=\frac{2MVI_z}{Y_\beta I_z+MVN_r} \quad . \quad . \quad (167)$$

The text of the paper here states that the response time is independent of static margin but this is only strictly true for positive static margins when the factor E is eliminated from the "response time" equation.

In addition, response time increases with speed and vehicle weight and is reduced by higher total cornering stiffness. For a given steered angle input a negative static margin car has the greater rate of response, since the final steady state amplitude is larger. However, for a given final amplitude, a positive static margin has the quicker response, but is associated with a greater value of steered angle.

(*To be continued*)

LITERATURE

British Railways in Action. By O. S. Nock, B.Sc., M.I.C.E., M.I.Mech.E. Thomas Nelson and Sons, Ltd., 36, Park Street, London, W.1. Price 25s.

In this book the author sets out to show by numerous examples some of the operating problems confronting British Railways in the everyday working of a complex and congested railway system. The overall picture is presented in a total of sixteen chapters extending over 225 pages of text, supported by forty-eight illustrations prepared from photographic views of much more than ordinary merit.

The operating problems, ably described, include, for example, train working over the old Somerset and Dorset Railway—"The Line over the Mendips," as the author calls his Chapter 1. The description given of the special difficulties encountered, particularly during the summer seasonal traffic conditions, is as charmingly portrayed as the delightful country through which the trains move from Bath to Bournemouth. The following chapters, still on operating problems, take the reader to the former Great Eastern section of British Railways; and to "Manchester—Focal Point of the L. & Y. System" largely given up to the working of the fast passenger morning and evening services between this point and Southport and Blackpool over one of the most complicated lines in the country.

"Modern Locomotive-Testing" forms the subject of Chapter 5. Here the author considers testing as conducted on stationary plants, such as those in use at the Rugby Testing Station and at the Swindon Works of the Western Region. What is called the Controlled Road system of testing as devised at Swindon is also fully explained. This is a very elaborate method, the purpose of which is to establish the performance of a locomotive when working a train of known weight over a given length of line at some pre-determined constant rate of steaming and, therefore, at a constant firing rate. Examples are given of certain Controlled Road Tests, one of which is a trial made with a "King" class express engine, first introduced on the Great Western in 1927. This was made when the firing rate was held at 4150 lb of coal per hour and the evaporation at 28,700 lb of water per hour. The coal consumption is given as being 3·3 lb per drawbar horsepower hour, meaning that the mean power developed was 1260 h.p. The train was made up of twenty-five vehicles giving a load of 781 tons behind the locomotive. The author is particularly well informed on matters relating to the Western Region and in this connection states that the maximum mean steaming rate laid down for the "King" class engines is 25,000 lb per hour. This is said to be the sustained rate, taking into account the possibility of inferior coal. Tests on the Swindon plant show that, with coal having a high calorific value of 14,510 B.Th.U. "as fired," there is produced an actual evaporation of 24,600 lb of water per hour, giving a steam supply to the cylinders of 26,000lb per hour including the steam returned to the boiler by the exhaust steam injector. The firing rate is then 3200 lb of coal per hour. What the firing rate might be if a lower grade of coal is used is a matter of conjecture; it would certainly be higher than 3000 lb officially held to be the maximum for one fireman for continuous working.

For some time past the modernisation of the signalling system at various points on British Railways has been given a large amount of attention. An outstanding and, in fact, unique example of what can be and has been achieved is to be found at York. This is fully described in Chapter 6, "York, Grand Junction for the North." The North Eastern Area of the L.N.E.R. was one of the first operating entities on British Railways to develop the idea of large centralised control points at which signalmen were given control of a far more extensive area than was possible in the days of mechanical signalling. The very extensive layout of the lines entering York has now been brought under the control of one large signalbox or control point, said to be one of the boldest experiments in railway traffic regulation anywhere in the world.

"Mineral Traffic on the North Eastern" is the title of Chapter 8. In this, an excellent account of the working of heavy coal trains is given and also of the working of iron ore trains from Tyne Dock to the Consett Iron Works. In direct contrast to the relatively slow and laborious movement of huge loads over a particularly heavy road described in the previous chapter, the following Chapter 9, "High Speed Running," is concerned with examples of extra fast running which has been recorded at various times either by the author or other competent observers. The two railways mostly concerned with what may be termed extra high speed running are the former L.N.E.R with the renowned Gresley "Pacifics" and the G.W.R. with C. B. Collett's "Castles" and "Kings," especially well known to the author, who is never quite so happy as when on the footplate of one or other of these Swindon creations.

The author's investigations into traffic working take him far afield, and in Chapter 10 we find him on the old G. & S. W. R. and on the Caley working out of the St. Enoch and Central Stations to Glasgow. Here a description is given of the working of "The Clyde Coast Lines of the Former L.M.S.R." Chapter 12 is notable as dealing with the newly electrified line over the Pennines between Manchester and Sheffield. The author describes the methods adopted for handling coal traffic originating at Wath-upon-Dearne which are operated over the exceptionally heavy grades between that point and Barnsley Junction, near Penistone, and from thence up to the summit at Woodhead Tunnel when travelling towards Manchester.

Other chapters not already mentioned have for their subjects, "West of England Holiday Workings," "A Miscellany of Specials" and "Motive Power for Continentals," each one of which makes informative reading. In conclusion, the remaining subjects are "Express Passenger Locomotive Working," Chapter 15, and the final Chapter 16 is given up to a number of "Logs of some Fine Runs," of which there are thirty examples. Perhaps some special interest will be found in some of the recorded observations concerning locomotives other than steam, namely diesel electric locomotives. These include the two older locomotives, Nos. 10,000 and 10,001 of the former L.M.S.R., which are of 1600 h.p. The later examples are Nos. 10,202 of 1750 h.p. and 10,203 of 2000 h.p., which have been operating on the Southern Region and also on the L.M. Region. The performance of the 1750 h.p. and 2000 h.p. units is shown in comparison with one of the Bulleid "Pacifics," West Country Class. The 1750 h.p. unit had a 365-ton train between Waterloo and Salisbury, and the 2000 h.p. engine, a 466-ton train. The steam locomotive had a load of 336 tons. The smaller diesel unit is stated to have been worked to capacity for the entire journey of 83 miles. On the other hand, the larger 2000 h.p. locomotive is said to have had more in hand, though on the more difficult stretches it was "for the most part working at practically full capacity." From Andover, 66·4 miles from Waterloo, up to the summit at M.P. 73·4, the rising grades vary at rates of 1 in 220, 1 in 264 and, finally, at 1 in 165 for about 3 miles with a short drop at 1 in 330 following the initial rise of 1 in 220 starting from Andover. On this length of line the steam locomotive was faster than the 2000 h.p. diesel, though this engine was going "flat out." The steam locomotive had the lighter train, though, on the other hand, the West Country class is the smaller of the Bulleid "Pacifics." Further, this engine seems to have been working throughout under relatively easy steaming and "had by far the greatest amount in reserve."

In conclusion, it may certainly be said that this new book by a now well-known writer fully reaches the standards set by previous efforts. The production is in every way very satisfactory.

Jane's Fighting Ships, 1956–57. Edited by R. V. B. Blackman. Sampson Low, Marston and Co., Ltd. Price £4 4s.

This book has been published annually for the past fifty-eight years and each year it brings our knowledge of the world's navies up to date by the amplification and revision of technical data and descriptive matter. The 1956–57 edition, with 440 new illustrations, is again well up to standard in accuracy and reliability. In these days of hydrogen bombs and ballistic rockets, *Fighting Ships* is now something more than a work of reference. It is also an annual reminder that if we are ever again to be faced with a major war, it will be fought at sea as well as in the air. For the reader who is not interested in precise figures and detailed comparisons, the publishers' foreword provides a comprehensive picture of the recent developments in the navies of the world. Of these, the most striking is the rapid ascendancy of Russia to the position of a major naval Power, second only to the United States. It is also noteworthy that, while the United States Navy is turning to atomic power for ship propulsion and to guided missiles for anti-aircraft defence, Russia continues to build ships of the conventional type with the conventional types of armament. *Jane's* refers to "a report that Russia is developing an atomic-powered submarine," but the main emphasis on her building programme is, in fact, on large submarines and on cruisers capable of operating far afield. Her aim should war break out would be to sever N.A.T.O. sea communications and to prevent American reinforcements reaching the Continent of Europe.

When discussing developments in guided missiles, however, the publishers are neither consistent nor entirely accurate. If, as they state, guided missile ships in the United States Navy are not considered to be a separate category of warships, it should not be necessary to specify that the ships

being built or converted in the current naval construction programme are guided missile cruisers, guided missile destroyers, and guided missile frigates. Moreover, while guided missiles have now replaced the gun for anti-aircraft defence, they are certainly not regarded as more modern anti-ship batteries. The strike aircraft and the radar-controlled gun remain, and are likely to remain for some time, the main armament of warships. Some U.S. battleships, carriers, cruisers, and even submarines are, it is true, now being equipped with surface-to-surface guided missiles. But these are of the winged variety, of the improved " V.1 " type, with a range of some 300 miles, and are merely a useful auxiliary to the main armament. They are not an effective substitute for aircraft. A reliable medium-range true-guided rocket is not yet in production for any navy. Turning to the body of the book, the pages dealing with the United States and Royal Navies make painful reading for those of us who remember that Britain became great through sea power. But the British Government has made it abundantly clear that our naval rearmament programme is based on our membership of N.A.T.O. and not on the ability of this country to stand on her own feet. We have thus no doubt been justified, in view of the large numbers of carriers and cruisers in the United States Navy and of our limited resources, in concentrating on the building of fast frigates, minesweepers and other small ships to counter the submarine and mine menace. *Fighting Ships* also shows that the Dominions are now making a valuable contribution to the Commonwealth naval strength. Canada and Australia each have, or will shortly have, two aircraft carriers. These four carriers are relatively slow, but H.M.C.S. " Bonaventure " and H.M.A.S. " Melbourne " are fitted with the angled deck and steam catapults and can operate Fairey " Gannets " and the earlier types of jet fighters. Canada, New Zealand and India each have two cruisers and Pakistan one, while South Africa is acquiring a fleet of fast anti-submarine frigates and coastal minesweepers to be built in Britain.

Robert Hooke. By MARGARET 'ESPINASSE. William Heinemann, Ltd., 99, Great Russell Street, London, W.C.1. Price 21s.

ON February 15, 1665, the day of his election to the Royal Society, Samuel Pepys mentions that after the meeting the party proceeded to the Crown Tavern (which was close to the Royal Exchange), " and there my Lord (Brouncker) and most of the company to a club supper ; Sir P. Neale, Sir R. Murray, Dr. Clerke, Dr. Whistler, Dr. Goddard, and others of the most eminent worth. Above all, Mr. Boyle was at the meeting, and above him Mr. Hooke, who is the most, and promises the least, of any man in the world that ever I saw." The two names most conspicuous in the above passage are those of Boyle and Hooke. Not only were they outstanding in the estimation of Pepys, who in 1665 was able to see and listen to them, but they remain outstanding to us nearly three centuries later. Robert Boyle we are likely to know better than we do his one-time laboratory assistant and lifelong friend Robert Hooke. Indeed, Boyle has come to be regarded as in the class with Pico della Mirandola and thus honoured both for his great learning and his saintly life. As for Hooke, while we may not equate him with Mirandola and Boyle, we hold him in high admiration both for his singular gifts as a scientist and inventor and his staunchness as a friend. As a mechanical genius he was undoubtedly far ahead of Boyle. These observations are prompted by perusal of the finely illustrated account of the life and labours of Robert Hooke, which, written by Margaret 'Espinasse, was recently published in the Contemporary Science Series. Mrs. 'Espinasse describes him as a " brilliant, generous, unlucky man," and it is indeed very true. Even to-day the name of Hooke is comparatively little known, though of late years the publication of specific details relating to his work—hitherto hardly recognised—in the rebuilding of London after the Great Fire has tended to raise the curtain surrounding him. Mrs. 'Espinasse now goes a long way towards removing the curtain altogether and in so doing brings into the light of day the Hooke who was set by Pepys above Boyle. The circumstances which brought about—not long after his death—a decline in the reputation of Hooke amounting almost to extinction, are summed up by Mrs. 'Espinasse in the following paragraph from her chapter entitled " Hooke and Newton " :—

" It seems probable that his reputation suffered this extraordinary eclipse chiefly because he had incurred the enmity of Newton. The neglect of Hooke cannot be attributed merely to the customary change in scientific interests and attitude which a new generation brings about, for in that case Boyle's reputation should also have suffered, and it has not. Boyle was a friend of Newton's."

For the detailed account of the personal and controversial considerations which chequer the life story of Hooke those interested may be referred to information now made available by Mrs. 'Espinasse, and a remarkable story it is. As to the strictly technological aspects of Hooke's work, we may well marvel that such a genius could remain so comparatively unknown. Mrs. 'Espinasse affirms that " Hooke came very near the early ideal of a scientist whose field is the whole of knowledge. There was hardly a branch of science he did not know a good deal about, nor of art either." It might be affirmed that there are few inventors who, without pecuniary advantage to themselves, have better earned the respect and gratitude of posterity than has Hooke. If early controversy still renders it difficult to be quite certain as to the identity of the creator of the spiral balance spring for watches, Hooke proposed the universal joint. He invented the iris diaphragm for telescopes, which, as Mrs. 'Espinasse points out, is " now used by everyone in their cameras." He enunciated the law of spring and was the inventor of the dividing plate used in gear cutting. He proposed the wheel barometer and made suggestions which hastened the evolution of better watches, telescopes, microscopes, air pumps and other instruments and equipment. In all these labours Hooke was actively promoting the scientific progress which renders so luminous the history of the second half of the seventeenth century.

In connection with his architectural work, Mrs. 'Espinasse relates how " Hooke suggested that an inverted catenary—a catenary being the curve of a flexible chain hanging freely from two points of suspension—would provide a stable arch. Wren and Hooke had already discussed this problem of the arch before the Society in 1670 and 1671, and as City Surveyor Hooke had, of course, been working with Wren on buildings and discussing architectural problems with him since 1666. In view of the fact that ' the pillars and cone of St. Paul's closely follow the form of a catenary,' it is interesting to read in Hooke's Diary for 5 June 1675 that Wren ' was making up of my principle about arches and altered his module by it.' " In London, we have a perpetual reminder of Hooke in the Monument, that great pillar which, long attributed to Wren, was built from the designs of Hooke. Very little else has survived of his buildings so that the information and illustrations relating to them enhance the interest of Mrs. 'Espinasse's book. As if to perpetuate the eclipse already referred to, there is no epitaph to Hooke in the Priory Church of St. Helen, Bishopsgate, where he lies in an unmarked grave. Perhaps his best epitaph would be found in the words of his friend and admirer, Samuel Pepys :

" Above all, Mr. Boyle was at the meeting, and above him Mr. Hooke, who is the most, and promises the least, of any man in the world that ever I saw."

Books of Reference

Ship and Boat Builder Annual Review, 1956. John Trundell (Publishers), Ltd., Temple Chambers, Temple Avenue, London, E.C.4. Price 40s.—As in previous reviews this year's edition opens with a series of articles of particular interest to the ship and boat builder. On the question of trawler building at home and abroad, Mr. A. L. Cochrane deals with the British point of view and Bertram Rickmers gives his views on trawler building and advances reasons for the British owner placing orders in Germany. Both points of view are summed up by Commander A. C. Hardy. Mr. E. J. March touches upon the history of timber in shipbuilding and Mr. J. W. Nicholson writes of the role of timber in present-day construction. " The Navies of the Future " is the title of an article by Mr. R. V. B. Blackman, and in " The Economics of the Diesel-Electric Drive " Mr. M. R. Horne reviews this form of propulsion. Other special sections in the review deal with new marine equipment, British small craft, radio and navigational equipment, and power tools in the boatyard. Particulars of boats launched in 1955 from the different yards are recorded and British builders and repair yards are listed in alphabetical order and classified geographically. Overseas boat builders are grouped alphabetically under their particular country. Separate tables set out the marine engine specifications of marine and auxiliary and of outboard units, and there are lists dealing with paint specifications, marine fittings, timbers, materials, yard equipment and manufacturers and suppliers. Additional to the lists dealing with materials are those which give lists of consultants, trade and learned associations, British owners of commercial and fishing vessels, dock and harbour authorities, British yacht clubs, and commercial diplomatic officers and trade commissioners.

Directory of Railway Officials and Year Book, 1956–57. Tothill Press, Ltd., 33, Tothill Street, London, S.W.1. Price 40s.—The sixty-second edition of this well-known book of reference has been extensively revised and rearranged. To facilitate ready reference all the countries of the world—with the exception of Great Britain and Ireland—have been arranged in alphabetical order, and all the railways, large or small, of any one country have been brought together. Additional information which has more recently become available on the railways of Argentina, Czechoslovakia, Jugoslavia, and the U.S.S.R. has been included in the new edition. A general revision of the statistical sections has been based on extensive inquiries all over the world and many important adjustments have been made to the tables.

Books Received

Calenders for Rubber Processing. By H. Wilshaw. Institution of the Rubber Industry, 4, Kensington Palace Gardens, London, W.8. Price 25s.

Herburg Spannbetonbau Teil I. By Dr.-Ing. habil. Wolfgang Herburg, B. G. Teubner Verlagsgesellschaft, Leipzig, Germany. Price DM. 21,80.

Tinplate Handbook. Third edition. By W. E. Hoare. The Research Institute, Fraser Road, Perivale, Greenford, Middlesex. Available free of charge.

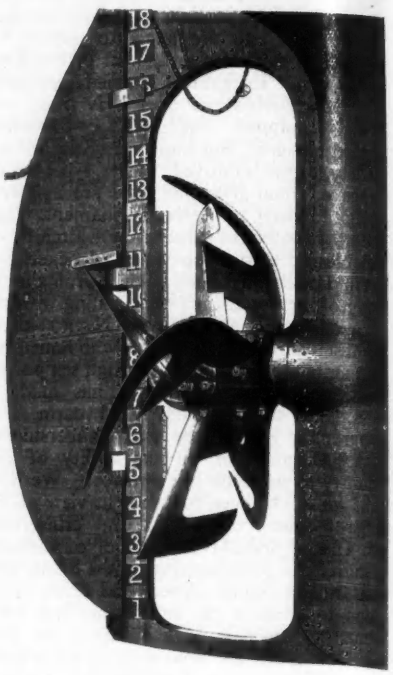
The Economics of Electrical Installation Design. By G. H. Wedge. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, London, W.C.2. Price 45s.

The Time for Decision, "An Industrialist Looks at Life." By Francis B. Willmott. Ripley, Preston and Co., Ltd., 360, Mosley Road, Birmingham, 12. Price 15s.

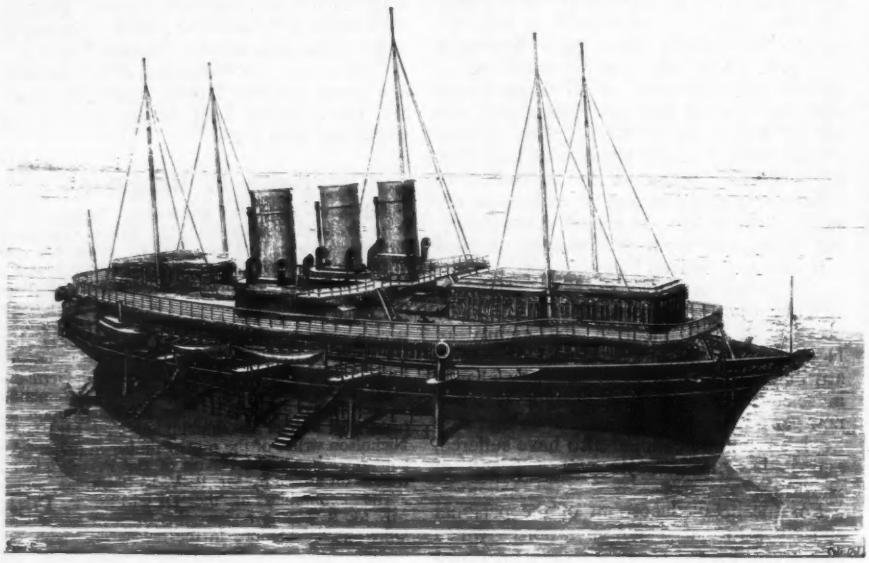
Drawing Office Handbook. Edited by R. W. Stuart Mitchell. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 16s.

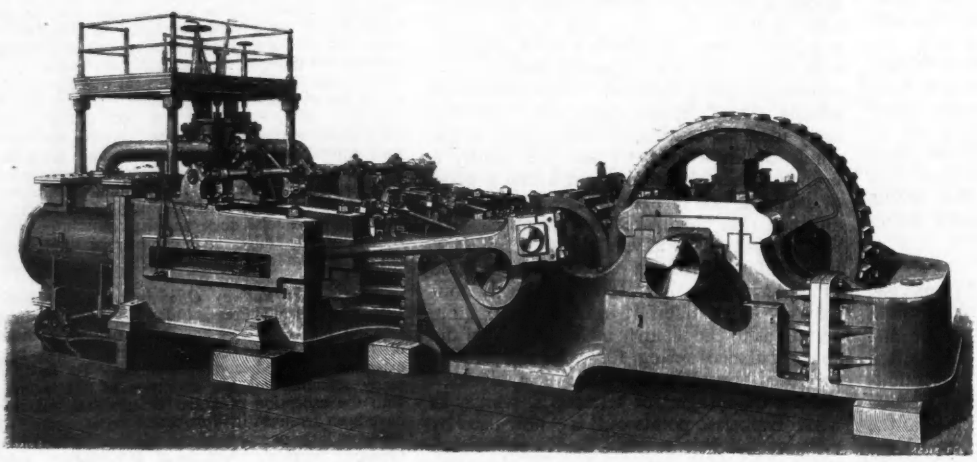
ENGRAVINGS OF 1880

The right-hand engraving, reproduced from our issue of August 20, 1880, illustrates the De Bay propeller which was fitted to the steamer "Cora Maria." Our description says that "each blade, instead of having a uniformly increasing pitch, has a pitch of 17ft to half radius, and increases therefrom from 19ft to 21ft. The propeller is 11ft in diameter."



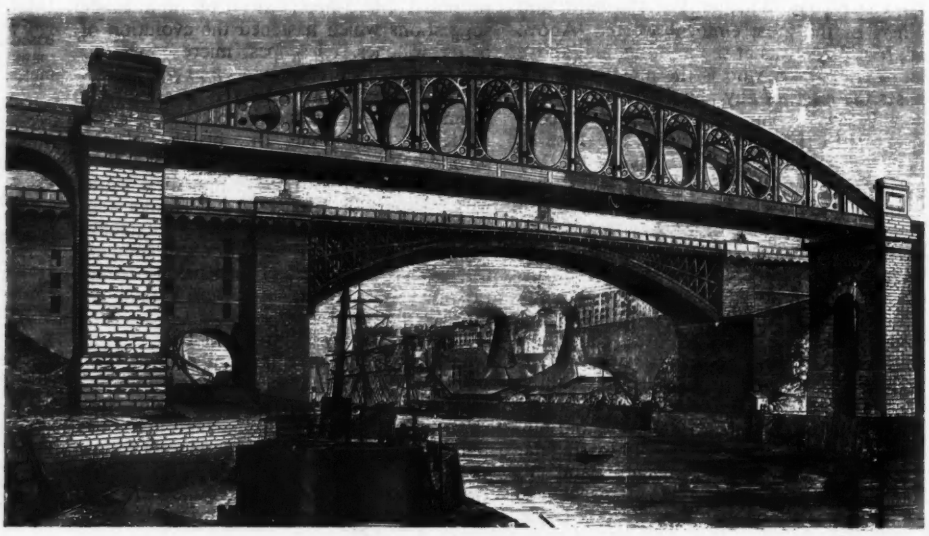
The "Livadia," which is illustrated in the engraving below, was a "famous yacht" built for the Czar of Russia by John Elder and Company, at Govan. The yacht was 235ft long. The engraving is reproduced from our issue of July 16, 1880.





Our issue of October 22, 1880, contains a description of some non-condensing cogging engines which were built by W. and J. Galloway, of Manchester, for Bolckow Vaughan and Company. This engraving (left) is reproduced from that issue. A pair of the engines were supplied for driving a 38in cogging mill. The whole of each engine, the description says, "is carried on one box-bed plate extended to carry second motion shaft and wheel, cast in suitable pieces and securely connected by bolts."

The right-hand engraving, from our issue of November 12, 1880, illustrates the North Eastern Railway Company's bridge over the River Wear at Sunderland. Mr. T. E. Harrison was the engineer responsible for the building of the bridge which we described as "one of the finest bowstring girder bridges ever erected." Our description goes on to say that "the bridge consists of one main span, with three 31ft semicircular arches on either side. The main span has a clear width of 300ft, and a clear headway of 86ft above high water." Our article adds: "the new bridge stands side by side with Robert Stephenson's celebrated road bridge, which is shown in the background of our engraving."



Newsprint Mill at Kemsley

No. I

An expansion and development programme at the Kemsley newsprint mill of the Bowater Paper Corporation, Ltd., has involved the construction of an additional newsprint machine of 60,000 tons per annum capacity, and a new electric power plant of 15,000kW, which incorporates a new coal-handling system and a boiler having a maximum continuous rating of 450,000 lb per hour of steam at a pressure of 1550 lb per square inch gauge and a temperature of 925 deg. Fah.

BEFORE the war the Bowater Paper Corporation, Ltd., had planned to erect an additional newsprint machine at its Kemsley Mill, near Sittingbourne, Kent, and in the post-war period the plans for expansion and development have been modified and adjusted to incorporate technical advances. Apart from the problems concerning the final design, construction and erection, of the newsprint machine, there were others related to the logistics of the supply of raw materials, including docking facilities, dock equipment, roads, rail systems, and rolling stock, conveyor systems and storage arrangements. Similarly, the distribution of some thousands of tons of the finished product had to be given consideration and organised, together with the provision of additional storage for reels. Besides making provision for the inward and outward flow of raw and finished material, there remained the need to plan a new preparation plant for the feed stock, including mechanical handling equipment, and the question of the design of a new power plant to provide steam for process and for the generation of the electrical energy to drive the mill motors.

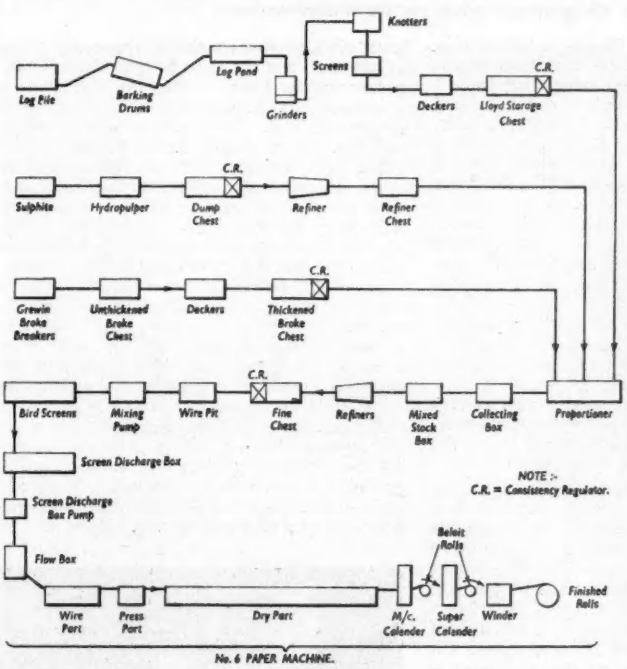
For the manufacture of newsprint only a few raw materials are required: they are mechanically ground wood pulp, chemically prepared pulp, together with small quantities of china clay and certain chemicals. All these items, together with coal for the boiler plant, have been received and unloaded at Ridham Dock; however, the increased quantities to be handled called for some reorientation of the supply organisation, and a new coal jetty was built in the River Swale. This made an additional berth available on the west side of Ridham Dock for the importation of pulpwood and also extra space on the dockside with the removal of the old coal bunkers and storage yard. Large quantities of water are required, but no additional provision has had to be made for this, since the company possesses adequate supplies of water from an underground source.

The new No. 6 machine at Kemsley is designed for an output of about 60,000 tons of newsprint per annum and to produce a paper sheet 270in wide at about 2000ft per minute, which will be wound on reels holding 12 miles of newsprint. In the machine house the space occupied by the mill is approximately 555ft by 70ft and the operating floor is of reinforced concrete slab supported on steel joists and columns, while the machine soleplate is carried on twin 27in by 7½in R.S.J.s. The various chests and tanks at ground floor level are of reinforced concrete.

Preparation of Stock

The accompanying diagrammatic flow chart indicates the stages in the production of newsprint. From the log piles, to which the pulpwood has been delivered from Ridham Dock by overhead conveyor, the logs are removed by means of a conveyor and arrive at the barking drums. These rotate and remove the bark from the logs, which pass through in a continuous flow to arrive at the log pond. From here they are fed into a flume, along the length of which grinders are placed in pairs at intervals on each side. Operators pull the logs, all of standard length, from the flume into chutes which feed the box holders of a Lloyd grinder. A sliding plate in the bottom of each holder controls the entry of the logs into the magazines, where hydraulically-operated shoes force the logs against the face of a grinding roll of artificial stone or carborundum from both sides. The wood fibres drop into the ground stock channel and the grinding rolls have a life of six to nine months and two years respectively. Another design of grinder in use is the continuous vertical magazine pattern, in which the logs are fed in at the top of the magazine from a mechanical conveyor and forced downwards against the face of the grinding roll by twin slowly-moving spragged linked chains. Also employed is a battery of four-pocket grinders, in which the four pockets are manually supplied with logs in rotation and the logs are pressed against a stone grinding roll by a hydraulic ram.

In each instance the large pieces of wood are removed in the primary screens before the ground stock is pumped up to the knotters floor and passes down through a succession of screens,



Diagrammatic flow chart of the preparation plant and No. 6 papermaking machine

from which the accepted stock flows to the fine screens.

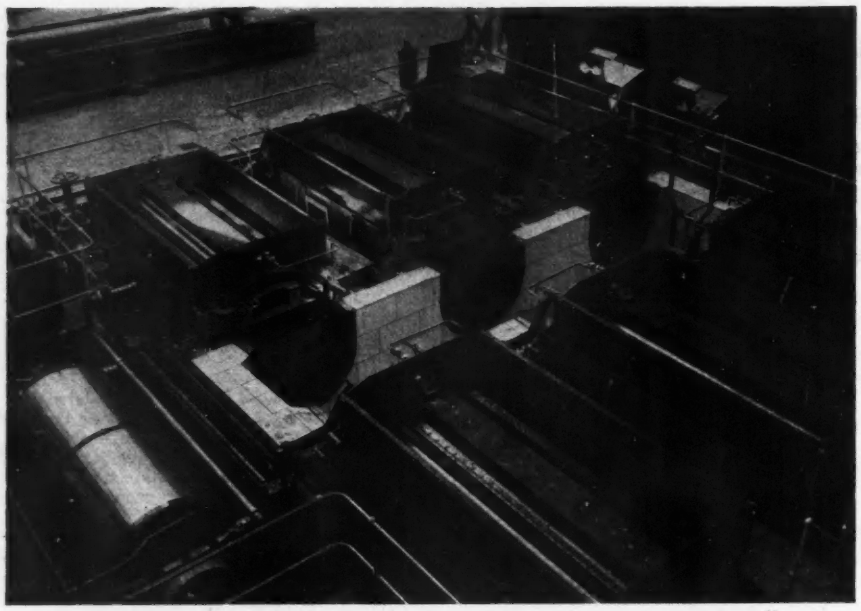
At the next stage the stock enters a decker machine, which is a dewatering device consisting of a drum, covered with a phosphor-bronze mesh, revolving in an outer casing. The stock enters the outer compartment as a 2 per cent solution and some water is drawn off through the drum surface, leaving a 3 per cent stock to be pumped to the large concrete circulating Lloyd storage chest. This has a capacity of 225,500 gallons or 30·2 air dry tons of stock at 3 per cent consistency. The chest is divided into two channels by a mid wall and has semi-circular ends where impellers are mounted. They keep the stock (which is slightly denser than required so as to save space) constantly in circulation. There is a consistency regulator fitted to the chest and this constantly takes samples of the stock and adds water for dilution as required. From the Lloyd chest the stock is forwarded to the proportioner, where it is mixed with the other materials required, including chemically prepared pulp or sulphite.

The sulphite arrives by ship at Ridham and is moved by rail to the stocking area at Kemsley and then as required is transported again by rail and then by slat conveyors to hydropulpers. These are bowl-shaped vessels with an impeller at the bottom and in which the sulphite is mixed with water to a 4 per cent stock. This is pumped to a dump chest, fitted with a consistency regulator, and afterwards is passed through a refiner of double cone design, where water is added and the brushing action of ribs, in the annular space between the cones, breaks up any knots of fibre. The refined sulphite stock goes to the refiner chest, where it is held ready to be supplied to the proportioner. The other main material included in the production of newsprint is a proportion of prepared broke paper. Broke paper from each calender and the winder drops into a shallow concrete trough under each machine, and is washed down with water to one of three Grewin broke breakers. Then as unthickened broke it is pumped to a large concrete storage chest, afterwards passing through decker machines to the thickened broke chest, which is fitted with a consistency regulator, before being forwarded to the proportioner.

At each feed chest to the proportioner is a paddle, the paddles being of different sizes and driven at varying speeds, which serves to supply the right amount of each of the raw materials to produce the correct mixed stock. This flows from the proportioner to a collecting box and then on to the mixed stock chest, followed by treatment in a pair of double-cone pattern, No. 5A size, Walmsley/Jordan refiners, each driven by a 350 h.p. motor, before arriving at the fine chest. From the latter the mixed stock is pumped to a consistency regulator, where water is added to produce a consistency of 200 parts of water to 1 of fibre, from where it flows to the wire pit into which also flows the water abstracted from the endless wire section of the machine. A mixing pump draws the stock from the wire pit and passes it to a battery of six size 3A motor-driven Bird screens, each of which consists of a cylindrical drum, having groups of circumferential slots, carried in a vat which is vibrated. The mixed stock is fed into the vat and passes through the slots to the interior of the drum and thence to the screen discharge box. Operating in conjunction with the Bird screens is a Watford "inward-flow super-tremor" strainer, which recovers a certain amount of accepted stock from the stock rejected by the Bird screens. The Bird screens and the Watford strainer can be seen in one of our illustrations.

No. 6 Paper Machine

The stock is now ready to be made into paper and enters the wet end of the machine via a flow box, to which it is pumped, by a pump having a capacity of 15,000 gallons per minute, from the screen discharge box. The "Beloit" pressurised combined stainless steel flow box and slice has twin stock inlets, a stock chamber with an adjustable front carrying the slice, five adjustable rectifier rolls and a stream flow valve. In the chamber, which is 286in wide by 96in long by 66in high, the stock is under air pressure which provides an artificial head and can be controlled to suit the speed of the wire screen and which replaces the old system of a direct hydrostatic head. From the stock outlet the mixture of water and fibre flows on to an endless phosphor-bronze woven wire screen, 292in wide, which travels at speeds up to 2050ft per minute and



Group of Bird screens and the Watford strainer

has a length of about 115ft and a fall of 12in from breast roll to suction couch roll in a length of about 49ft. The screen table after leaving the rubber-covered breast roll passes a forming box before reaching the first of the table rolls, of which there are sixteen. Water from the stock drains through the wire screen, which passes over a group of four 12in wide suction boxes and a second group of three boxes, all of which are oscillated in a lengthwise direction, then over the suction couch roll to the cast bronze forward drive roll. Both these rolls are driven through gearing from a single motor, and the wire returns underneath the table bed via five tensioning and guiding return rolls, the first of which, together with the breast roll, is equipped with oscillating Vickery spring finger doctors for removing any particles of fibre adhering to the rolls. The vacuum boxes and the suction couch extract water from the stock to leave a wet mat of paper. In the photograph reproduced can be seen the wire table leading to the press section.

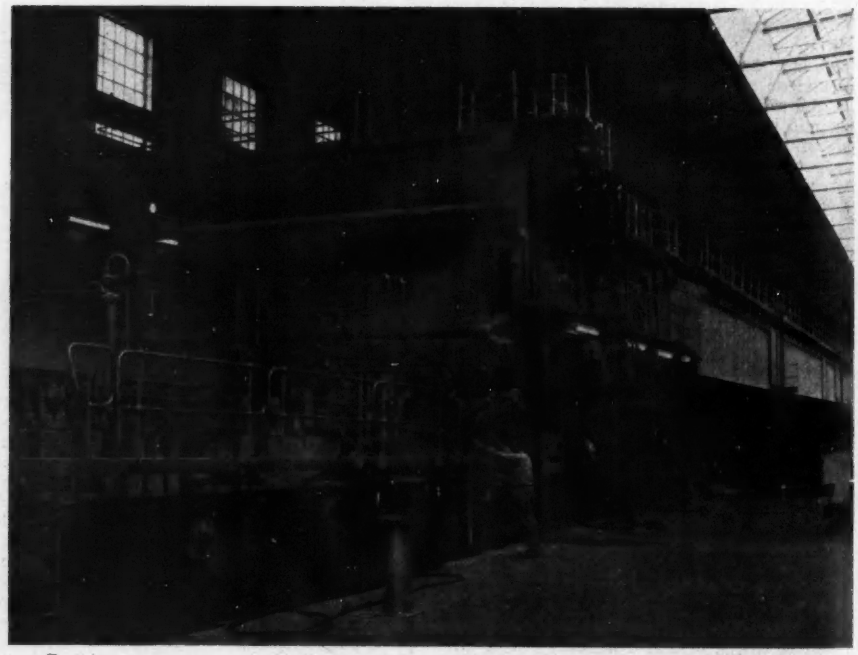
At the beginning of the press section and in close association with the suction couch is a rubber-covered vacuum pick-up roll where the paper web is lifted off the wire by suction on to the underside of a pick-up felt, about 80ft in length, and is carried forward to the first suction press rolls, consisting of a rubber-covered lower suction roll and an upper roll of polished granite. At this press a second felt is introduced from below so that the paper is sandwiched between the felts and at the same time is transferred by vacuum to the top side of the lower felt, while the top felt passes up over a guide roll and returns via tensioning rolls and a wringer press, where the water taken up from the paper is removed, to the vacuum pick-up roll. The first bottom felt carries the paper web to the second press and then just before reaching the third press a second bottom felt is introduced, the first felt returning via guiding and tensioning rolls, which serves to forward the paper web to the leading drying cylinder, of cast iron and steam heated, in the dry part of the machine. The bottom felts, 80ft and 62ft 6in long respectively, and the pick-up felt, have felt stretchers.

The second and third presses are similar to the first, the lower rolls being of 44½in diameter by 291in face width, the corresponding dimensions for the top rolls, which are fitted with Vickery doctors, being 33in and 292in respectively. There are six air-operated compounding units, for raising and lowering the top rolls, and for applying nip pressure at the three presses, and a total of thirty-one vulcanite-covered, wet felt rolls. The vacuum installation, of Sulzer design, is controlled by an automatic vacuum regulation system and consists of two radial-turbo-blowers. One has three branches: the first is connected to the first and second vacuum boxes of the suction couch roll, the second to the wringer roll, and the third to the suction boxes. Blower number 2 has two branches, one of which is connected to all three presses and the other to the pick-up roll. Both blowers are driven by 1400 h.p. motors at 6350 r.p.m. and 6090 r.p.m. respectively. In the system, air from the suction boxes, &c., passes through primary and secondary separators, in which the water abstracted is drained to the wire pit, and passes on to the blower. Discharge air from the blowers provides the hot air required for drying the felts.

In the dry part of the paper machine there is a total of fifty-three drying cylinders, heated by steam at 50 lb per square inch, one leading roll, a final cooling cylinder, and six felt driers arranged in three sections. This is largely determined by practical considerations such as the length of felt being operated and the amount of water pick-up. The felts in each section return via dryers. All the drying cylinders have a diameter of 60in by 286in face, as has also the cooling cylinder, which has a water nozzle and plain outlet, while the drive is from three end-drive pinion shafts and gearing. There are 110 dry felt rolls, and three top and three bottom hand-operated felt stretchers, and each felt is provided with a Beloit diaphragm operated auto felt guide. Also forming part of the equipment of the machine is a Sheahan feed system, arranged in three sections, which serves to initiate the paper travel through the mill. The drying cylinders are arranged in upper and lower sets with felt rolls in between and the paper travels alternately from a lower to an upper cylinder, along the length of the machine, passing around the outer arc of each cylinder between a felt and the cylinder surface before moving unsupported to the next cylinder.

The paper leaves the dry part over the cooling cylinder and under a water-cooled spring leading roll to enter the top of the machine finishing calender having eight chilled iron rolls of varying diameters, all of which, except the lowest, are steam heated. All the rolls have Vickery doctors, and there is a cold air system of twenty-five blowers on each side of the calender. On the lead-out side there is a cambered bar and a spreader bar. The paper is worked down the calender and wound on to a 22in diameter reel shell by friction and a motor-driven 36in diameter Beloit reel drum, fitted with an oscillating Vickery doctor. When a predetermined amount is wound on the reel shell the shell is transferred from its position vertically above the drum to a horizontal position by transfer arms, driven by an electric motor through a "Fluidrive" coupling, to which are attached primary air cylinders. The main air cylinders act upon the support rail. Spray damper equipment and air feed equipment are fitted, the latter taking care of the tail from the last top dryer to the calender roll and from the calender roll to the Sheahan feed, which transfers the tail to the Beloit reel, the tail being cut by an automatic spiking device. One of our illustrations shows the machine calender and Beloit reel at the dry end of the mill together with the roll position changing gear.

To improve the finish of the paper there is a super calender, which accommodates ten rolls, including a 36in diameter chilled iron bottom roll, a 26in diameter chilled iron top roll, two steam-heated 20in diameter chilled iron inter-rolls, and six inter-rolls of woollen paper. The maximum operating speed is 2500ft per minute and the nip pressure at the bottom roll 1000 lb per inch of roll face, while the unwinding stand can take a reel of 88in maximum diameter and has both front and rearside alignment for the paper reel, also cross alignment and constant tension control. All the chilled rolls are equipped with Vickery doctors and there are two leading



Wet end of No. 6 machine and wire table leading to the press section with the dry section to the right

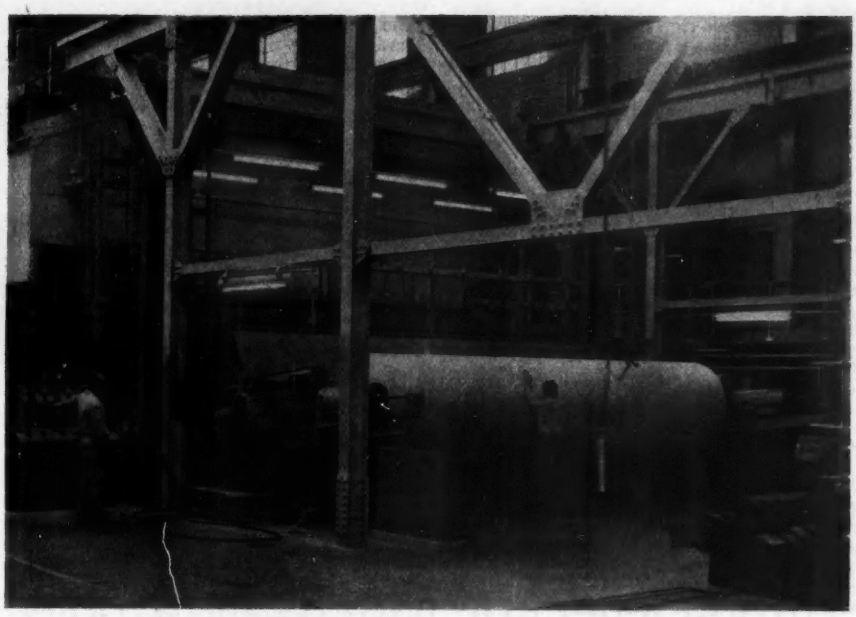
rolls, one above the other, on the ingoing side. Other equipment includes a travelling cross platform operated by electro-hydraulic and photo-electric cell equipment, and an electrically operated paper threading platform on the finished side.

For handling the paper reels there are two Butterley transporters having two sets of twin hooks, light and heavy, and designed to expedite roll changing. The main twin light hoists have a capacity of 2½ tons, while the twin heavy hooks have a capacity of 20 tons for the 88in diameter reels. The following is the sequence of operations : the light hooks pick up the empty reel shell from the unwind stand at the super-calender and transfer it to the first winding position at the machine calender and the heavy hooks then pick up the full reel, in the second winding position at the machine calender, and transfer it to the unwinding stand. Similar operations are carried out between the super-calender Beloit reel and the winder unwind stand. The paper from the full reel is unwound through the super-calender and then passes over a paper leading roll to a Beloit reel. The super-calender can be seen on the right of our illustration, which also gives a general view of the mill looking towards the wet end. After receiving its final polish the paper is transferred to the " Camachine Imperial " winder, which has an operating speed of 5000ft per minute for 270in trim width, producing finished reels of 42in diameter. The machine has a twin drum drive and a counter-balancing roll and slitter units having 9in diameter cutter wheels mounted on a hydraulically operated bar. In addition to supplying the 1400 h.p. motors for the Sulzer vacuum blowers and the 250 h.p. a.c. motors for the mixing and screen pumps, the British Thomson-Houston Company, Ltd., has provided most of the larger drives. The paper machine, which is arranged for a speed range of 900ft to 2300ft per minute, is driven by a multi-motor-generator electronically controlled drive. There are ten separately controlled sections with " Helper " drives at the wet end and the motors which drive the various sections through gearboxes and Wellman-Bibby couplings are as follow :—

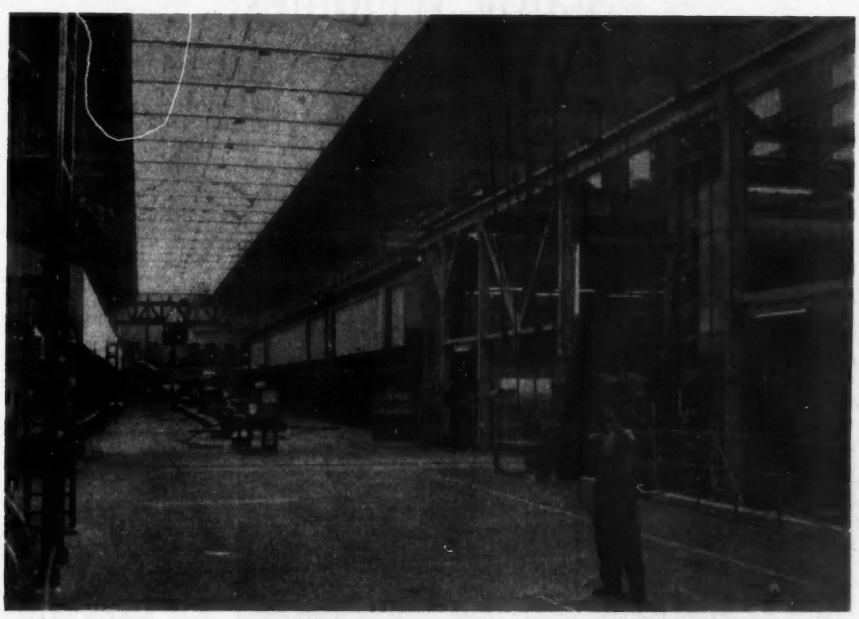
	H.P.
Couch and forward drive rolls	550
First return wire roll	20
Pick-up roll	50
Wringer suction press	150
First suction press	275
First suction press top roll	50
Second suction press	275
Third suction press	275
First dryer section	550
Second dryer section	550
Third dryer section	550
Calender	550
Beloit reel	150

The main drives for the wet end of the machine are shown in our illustration below, which also includes the blowers on the right.

Two 1400 h.p., 6·6kW synchronous motors drive two d.c. multi-generator sets, each generator of which supplies an individual indriving section motor. The speed of each motor is accurately controlled to within 0·1 per cent by tachometer



Dry end of machine showing machine calender and Beloit reel



Wet end of the mill with super-calender on the right

Main drives for wet end of mill; to the right, the turbo-blowers

Braking generator of 5000ft-per-minute winder

and an electronic regulator of the withdrawable tray pattern. This is accomplished by the tachometer generator providing a voltage, proportionate to the speed, which is compared with a reference voltage and the difference amplified and applied to grids of the a.c. driven thyratrons of which there are two pairs. These control the field winding excitation of the generator supply motor which is being controlled. Provision is also made for varying the reference voltage of each section, so that each section can be adjusted to compensate for paper stretch. An off-crawl-run switch, a draw rheostat and a slack take-up button are the controls for each section. This multi-generator plus electronic control arrangement gives a high degree of accuracy of speed control, and there is a fast non-oscillatory response over the speed range which keeps the transient effect of load changes to a minimum.

For the super-calender there is an 850 h.p., 6·6kV motor driving a 600kW generator, which provides a variable voltage supply to a 750 h.p. main motor and a 90 h.p. wind-up reel motor. The latter is arranged to provide preset constant tension during production running. Although the minimum operational speed is 500ft per minute, the speed range is from 50ft to 3300ft per minute, while for crawling speed for feeding there is a barring motor, with centrifugal-overrunning clutch. A 60 h.p. braking generator is arranged for the unwinding reel set to handle the reels weighing about 17 tons. Difficulties in developing the control system were overcome by the use of amplidynes, which, despite the high reel inertia, enable the super-calender to be accelerated or decelerated, with reels having diameters ranging from 22in to 88in, without touching the tension control. During acceleration the braking generator on the unwind stand has to assist in this.

The winder drive is generally similar to that of the super-calender, and consists of a 160 h.p. main motor, with booster and amplidyne control, giving speeds up to 5000ft per minute, and a 100 h.p. braking generator (seen in our final illustration on page 853) on the unwind stand to provide preset constant tension.

(To be continued)

Turbo-Generator with Water-Cooled Stator Windings

A 30MW turbo-generator with direct-water-cooled stator windings has been built by Metropolitan-Vickers Electrical Company, Ltd., for installation in the Central Electricity Authority's Bold (St. Helens) power station, the consultants for which are Messrs. Merz and McLellan. This generator will be used to provide information, under service conditions, about direct-water-cooling of stator windings for generators now under development with outputs of 200MW and more.

THE first large electrical generator to be provided with water-cooled stator windings has been manufactured by Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester. It is a 30MW, 11·8kV, 3000 r.p.m. a.c. generator and its stator winding is cooled (much more effectively than with conventional systems) by circulating water through the hollow conductors of the coils. The water is in actual contact with the live copper and the insulation of the system, as described below, depends on the fact that the water, if sufficiently pure, has a resistivity high enough to serve as an insulator.

This machine, which is a prototype, is being installed at the Bold (St. Helens) power station of the Central Electricity Authority. With the co-operation of Mr. A. R. Cooper, controller of the North West, Merseyside and North Wales Division of the C.E.A., the machine is being supplied instead of one of the four Metropolitan-Vickers standard air-cooled 30MW generators which have been ordered for Bold power station. Two of the air-cooled machines have already been installed; apart from its water-cooled stator winding, the third generator, which is the subject of this article, is an exact duplicate of the air-cooled machines, the winding having been designed to fit the same size of stator core and slots. The purpose of this prototype installation at Bold is to demonstrate by its operation under normal power station conditions the practicability of water-cooled stators and to assist current development work on the design of the largest generators likely to be required in Great Britain or overseas. Developments of this kind in the cooling systems of large turbo-generators will enable greater outputs to be obtained from machines of a given size and weight and will be essential if single generators of more than about 200MW rating are to be built within the present limits of transport in this country. In this context we may recall the Central Electricity Authority's recent announcement (as recorded on page 797 of last week's issue) that 275MW single-shaft machines are to be ordered in the constructional programmes for 1959–60–61.

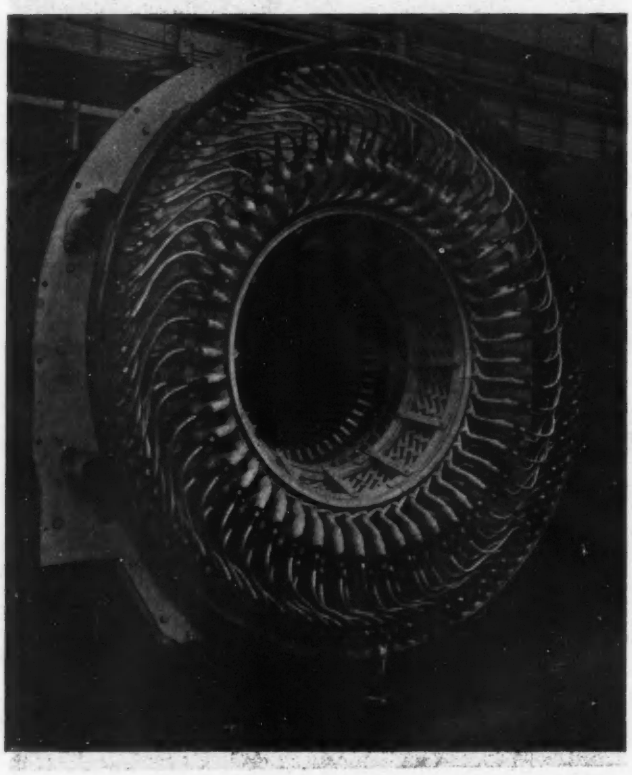
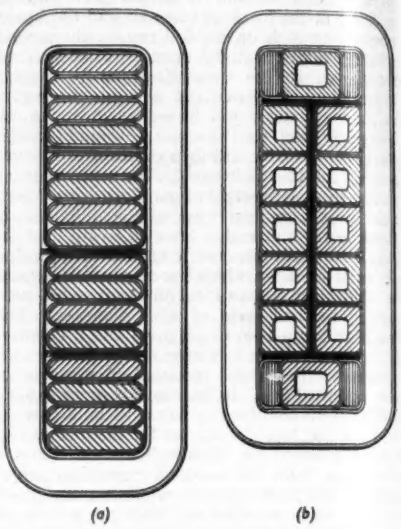


Fig. 1—End view of stator of 30MW turbo-generator showing water manifold and coil end connections

Present-day work on stator cooling is mainly concerned with the application of "direct" or "inner" cooling, whereby the coolant (either gaseous or liquid) is brought into direct contact with the live conductor which is, in effect, hollow. Heat is thereby abstracted directly from the conductor. In conventional systems, on the other hand, the coolant is circulated through channels outside the insulated conductor and the heat from the copper must pass to the coolant through the insulation. Direct cooling clearly provides much better conditions for heat transfer. For a given permissible temperature rise, which depends upon the insulation, the copper conductor can, therefore, be run at a higher temperature with direct cooling than with external cooling; the current-carrying capacity of a given size of slot can be increased correspondingly, which means that a greater output can be obtained with a given size and weight of stator.



(*a*) (*b*)

(*a*)—Conventionally cooled—cooling medium outside insulation.
(*b*)—Water cooled—cooling medium inside insulation.

Fig. 2—Turbo-generator stator conductors

In the system developed by Metropolitan-Vickers Electrical Company, Ltd., water was chosen as the coolant because of its good heat conductivity, its cheapness and the ease with which it can be handled by conventional pumping and cooling plant.

In Fig. 2 we show at (*a*) a section through the stator conductors of the conventionally-cooled winding of the two machines already installed in Bold power station, and, at (*b*), a corresponding section through the new water-cooled winding, which consists of twelve hollow-tubular strands, through each of which the cooling water is circulated.

These strands are transposed to reduce eddy currents and the transposition accounts for the apparent assymmetry of the top and bottom strands at the particular cross section shown at (*b*), Fig. 2. Because of this transposition each conductor strand is lightly insulated from its neighbours. The sections (*a*) and (*b*) are drawn to the same scale to give an approximate idea of the reduction in the overall size of the insulated conductor and the saving in copper achieved by water cooling of this 30MW machine. It may be deduced from the test results published below that an even greater saving could be achieved in a machine of the order of 200MW capacity. For this prototype winding the wall thickness of each of the tubular strands of copper is about $\frac{1}{4}$in, but we learn that the manufacturer has obtained satisfactory results with similar tubes of $\frac{1}{8}$in wall thickness.

The key to the success of this system of cooling

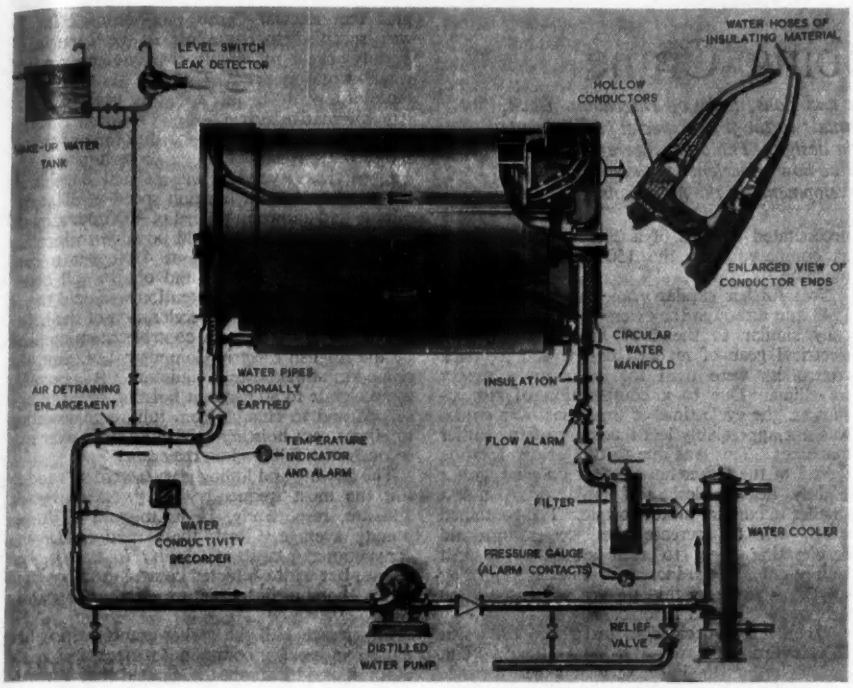


Fig. 3—Water cooling system for stator winding of a turbo-generator. Distilled water is pumped via inlet and outlet manifolds through the hollow conductors in a closed water circuit which includes filter, cooler and conductivity recorder

lies in the method of providing water-tight joints and insulated end connections for the coils of the stator winding. Insulation between the coil ends and the rest of the water coolant circuit is by separate tubes of a special plastics material. The watertight joint between the plastics insulating tube and the coil end is shown in section in Fig. 4. It will be seen that the "live" end of the tube is gripped between a stainless steel insert and a swaged ferrule of copper. A leak-proof joint between this insert and the stainless steel header insert is provided by an "O"-ring and a stainless steel nut which is locked to the header insert by tack welding. The junction between the circular cross section of the header insert and the rectangular cross section of the hollow strands constituting the coil ends is made by a copper header. The joint between the stainless steel header insert and the copper header is made by high-temperature brazing at about 900 deg. Cent. Lower-temperature brazing is used for the copper-to-copper joint at the coil ends. Insulation of the end connections is completed by glass tape wound on by hand and impregnated with bitumen (Fig. 1).

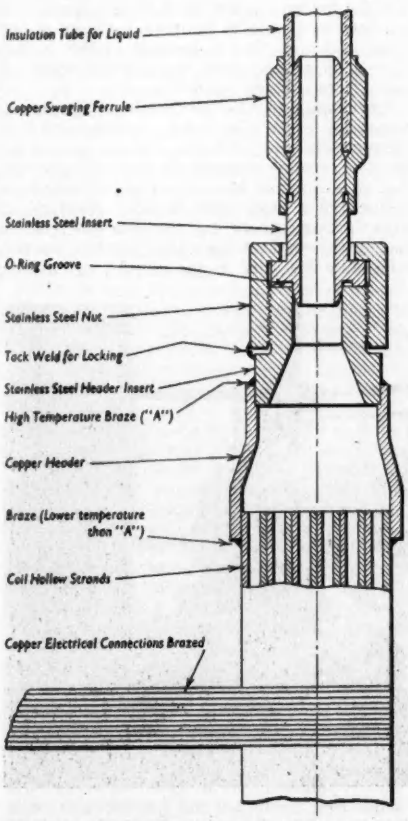


Fig. 4—Water-cooled stator coil-end connections

Various works tests have been applied to this type of joint. They include hydraulic tests at pressures in excess of 100 lb per square inch and artificially produced vibration tests at 50 c/s to give an amplitude of $\frac{1}{8}$in.

In Fig. 1 we show the 30MW generator stator with the cooling water connections in position prior to a test at approximately full kVA at the manufacturers' Trafford Park works. The flow of water is from one end of the machine to the other through all the conductor strands in parallel. Water flows from a manifold at one end of the stator, passing through the separate tubes of plastics insulating material connected to each conductor. Similar tubes at the other end of the stator convey the water to an outlet manifold. An air bleed pipe can be seen connected to the top of the water manifold in Fig. 2.

The diagram (Fig. 3) shows the water circuit with duplicate pumps and coolers, strainer, flow alarm, water temperature indicator, temperature alarm and conductivity meter. The water circuit is supplied from a header tank above the machine, with a float level alarm for detecting leaks. The water pipes are normally earthed but insulation is provided between the water manifolds and the stator frame and water pipes at both ends of the stator, so that insulation tests can be carried out on the winding *in situ*.

Standard works tests, using distilled cooling water with a conductivity of 2·5 reciprocal megohms per centimetre cube, were carried out, including open-circuit and short-circuit characteristics and losses, followed by a six-hour temperature test at approximately full rated load of 37·5MVA, 11·8kV, zero power factor. The total loss in the water in the plastics tube connections at this load is estimated to be less than 1kW, and it is stated that, even if Manchester tap water were used, the loss would not exceed 10kW. During the above test the maximum temperature rise of the distilled water was 2 deg. Cent., and the copper rise would only exceed this value by the water-to-copper surface rise, which is only 0·2 deg. Cent. The power to pump the water through the complete circuit was only 8·8kW, with a pressure drop across the winding of 18 lb per square inch.

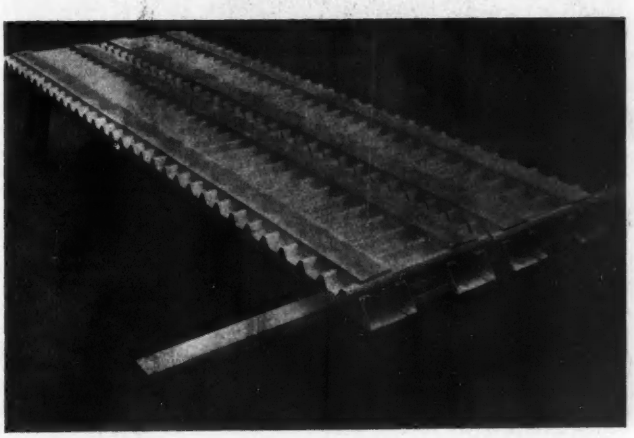
The above tests were followed by a three-phase sudden-short-circuit test at full voltage, and a final high potential test of 24·6kV for one minute between phases and to ground with water flowing through the conductors.

The conductor shown at (*a*) in Fig. 2 (which is the conductor fitted in the stators of the existing 30MW conventionally cooled generators at Bold power station) has a temperature rise of about 65 deg. Cent. measured by thermocouple between coils outside the insulation, for a current loading of 1835A, and with cooling air at 35 deg. Cent. The corresponding copper temperature is estimated to be about 115 deg. Cent.

During the works tests the water-cooled conductor (*b*) in Fig. 2 carried a current of 1750A for five hours, after which the copper temperature was 29·2 deg. Cent., the inlet distilled water temperature being 27 deg. Cent. It is, therefore, capable of carrying a very much larger current within the permissible temperature limits for the insulation in contact with the copper.

Aluminium Portable Bridge

PART of the equipment of the Commonwealth Trans-Antarctic Expedition is an aluminium alloy portable bridge. The bridge, two units of which can be seen in our illustration, is 14ft in length and is intended to span crevasses 10ft wide, while the vehicles which it has to support consist of 4-ton tractors having four pontoon tracks, each equipped with spikes for manœvrability on ice; 3-ton tractors having simple crawler tracks and sledges, with runners 8in wide. To keep the weight and size to a minimum while at the same time making provision to take three different widths of tracks, the bridge has been made in two longitudinal units, each 30in wide, which can be spread as required. The material has been provided by the Northern Aluminium Company, Ltd., and each unit is of simple decked girder construction, consisting of four lipped channel sections supporting troughed sheet, 0·036in thick, with tubular spacers and light plate bearers at the ends. The decking is reinforced on top by a plastic filler and strips of timber 6in wide. The total weight of the bridge is 260 lb including 200 lb of aluminium alloy.



Two units of crevasse bridge for Commonwealth Trans-Antarctic Expedition

7½-Ton Grabbing Crane

We have received from Samuel Williams and Sons, Ltd., of Dagenham Dock, particulars of two 7½-ton grabbing cranes made to the firm's special requirements and incorporating some interesting points in design. The cranes were supplied by Stothert and Pitt, Ltd., and the notes describe how experience with earlier designs of this firm's cranes led to the developments in the new cranes.

DAGENHAM DOCK, on the north bank of the Thames, has been owned and operated by Samuel Williams and Sons, Ltd., for just over a century, and the firm has always been closely concerned with bulk handling equipment, upon the efficiency of which its business largely depends. In 1950 the firm decided to install two new cranes on one of its jetties which had been extended, and the stages leading up to the design requirements of these new cranes can be traced back to 1937, when three grabbing cranes were introduced for the discharge of colliers, either overside into barges or into the hopper of a coal screening plant. These cranes, supplied by Stothert and Pitt, Ltd., are of interest as they form a basis of comparison for the later machines, although they are by no means out of date by contemporary standards.

These 1937 cranes were orthodox machines of 7½ tons capacity with a hoisting speed of 200ft per minute, a luffing speed of 130ft per minute, and a slewing speed of 1½ r.p.m. Wound rotor a.c. motors with plain rotor control were used on all the motions and no form of electrical braking was fitted. The drums for the mechanical brakes of the hoist motion ran at the 730 r.p.m. motor speed, one of the drums being used for the foot brake and the other being electrically operated by a B.T.H. thruster. In 1946 a crane of similar design, ordered from the same makers, had a hoisting speed of 250ft per minute. It was fitted with counter current braking on the hoist motion and two large brake drums were again fitted on the motor shaft. This increase in speed and braking duty necessitated the use of a 200 h.p. hoist motor as compared with the 150 h.p. of the 1937 machine.

Two further similar cranes were installed in 1948 and although they were generally mechanically similar to the 1937 machine, they had electrical gear of modern design and joy-stick controllers were used for all motions except travelling. Due to a combination of circumstances, the cycle time of these post-war cranes was not appreciably less than that of the earlier machines. This was due to the greater rotating inertia of the larger hoist motor coupled with a slightly heavier design of brake drum and a smaller maximum motor torque. The combined effect was to increase the accelerating and decelerating times to such an extent that it largely nullified the increased maximum hoisting speed. Apart from this, the cranes proved to be very successful and reliable.

When it was decided to order new cranes in 1950 investigations were made into the pros and cons of cranes having a very high performance and an equivalent capital cost to cranes with a higher load-lifting capacity and normal performance ; or a larger number of smaller cranes also of standard performance. On the score of interchangeability of grabs, it was agreed that it would be unwise to add cranes of a different capacity to the existing equipment, and the problem sorted itself into high performance versus orthodox equipments. The two cranes which were finally purchased by Samuel Williams and Sons, Ltd., from Stothert and Pitt, Ltd., incorporate a number of interesting departures from the makers' usual practice, which were dictated mainly by the special conditions of operation at Dagenham Dock, where the grabbing of bulk cargoes at high output rates is the primary duty.

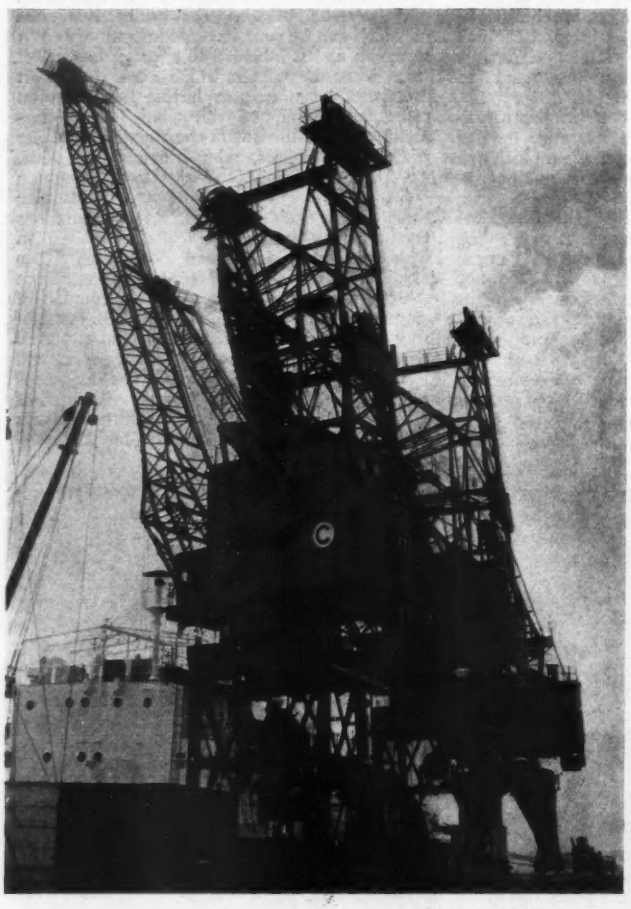
The new cranes can be seen in operation in one of the illustrations on this page. They have a rated capacity of 7½ tons for grabbing duty at 85ft maximum radius, with a minimum radius of 25ft and a tail radius of 17ft 9in. The total range of lift is 80ft, plus the necessary grab pull-out of 23ft. It was specified that the cranes be capable of a duty cycle of about twenty-eight seconds when working from ship to barge laying outboard, with a lift for this cycle of 30ft. An alternative cycle when slewing through 150 deg. was also specified with a time of thirty-six seconds when loading into a hopper. To achieve these cycles it was at first considered necessary to have a hoisting speed of 350ft per minute and a lowering speed of 400ft per minute, but it has since been found possible to increase both these speeds to about 450ft per minute without loss of control, and obtain still better cycle times. Particular attention was paid to the rate of acceleration and deceleration of the hoisting gear, by using a special control system supplied by the English Electric Company, Ltd., and the reduction of inertia to a minimum. It is possible to accelerate to 80 per cent hoisting speed in one second and to change from full speed lowering to 80 per cent hoisting speed in a little over two seconds with full load on the crane.

The slewing and luffing speeds were selected to suit the most frequently used working cycles, and are, respectively, 1½ r.p.m. and 175ft per minute average. Both these motions have a conventional a.c. drive, similar to the original cranes, but with contacted control gear operated by a combined miniature joy-stick master controller.

Experience with the earlier cranes, which had the triple reeving common to most designs of Stothert and Pitt cranes, suggested that a worthwhile saving in rope costs might be obtained over the life of the new cranes by sacrificing accurate level luffing and using a single part reeving over a high apex to give approximate level luffing. This system shortens the closing and holding ropes by one-third and has an added advantage in that the run-back of ropes from the jib to the barrel is less troublesome under slack rope conditions.

The most noticeable difference between the new cranes and the earlier machines is in the position of the jib foot pin, which is set at machinery bed level, and this position was chosen because of the single reeving over the high apex. The low pin position necessitated balancing the jib by the bell crank system, and the machines have twin cranks and rods following conventional practice. The difficulty of providing good visibility for the driver with a low jib foot position has been overcome by bifurcating the jib at the lower end and placing the cab in the centre. This arrangement gives an excellent field of vision from a seated position.

The decision to purchase these two high output cranes was made after a long investigation had been carried out into the various alternative forms of hoisting motions. It was originally felt that an a.c. motor having an exceptionally high torque and a long, small-diameter rotor might meet the requirement, but the idea was rejected because the inertia of this kind of machine was not sufficiently low, and it was difficult to provide



(Left) New 7½-ton grabbing cranes at work on jetty at Dagenham Dock. (Right) Driver's cabin of grabbing crane. This illustration gives an impression of the clear unobstructed view for operating and the simplicity of the controls

an effective counter current braking system which would be fully controllable (both plain counter current braking by plugging and braking by d.c. injection were considered). The form of Ward Leonard used was designed and supplied by the English Electric Company, Ltd., in which field forcing is applied to the generator by magnetic amplifiers, the control of which is taken from a potentiometer operated by the hoist controller. The potential acceleration and deceleration torques with this system are only limited by the characteristics of the motor and generator and the amplification of the magnetic amplifier. The normal drawback of a balanced grab system, namely, reduced acceleration during grab opening, therefore, no longer obtains. Full use has been made of this advantage, and about half the weight of the grab contents as well as the weight of the grab have been balanced off. This has reduced the cost and has enabled a smaller horsepower hoist motor to be used. It is anticipated that the cost of electrical consumption will be reduced by about £700 per crane per year on the basis of new crane loading cycles when compared with the original cranes.

In view of the low inertia of the motor armature, the energy stored in it is roughly equal to that of the low-speed hoisting barrel, the sheaves and the load itself. For this reason, the mechanical hoist brake is placed on an intermediate gear shaft between the motor and the hoisting barrel. This arrangement alone makes a substantial reduction in the total kinetic energy possible, the figure for the equipment being approximately one-seventh that of the earlier cranes, measured at the same grab speed.

The English Electric d.c. hoist motor is a steelworks auxiliary design, having a fabricated frame and an armature of low inertia. The nominal rating of the machine is 100 h.p., at 485 r.p.m., 230V, but a speed of 725 r.p.m. has been achieved by raising the armature voltage to 340V. The machine is insulated with class B materials, but under practical working conditions the temperature rise is well below that which demands the use of this type of insulation. The hoist motor is continuously force ventilated by a separately driven fan mounted on the motor frame and arranged to blow straight into the machine.

The motor generator set which supplies variable voltage d.c. power for the hoist motor comprises a 125 h.p., 981 r.p.m. squirrel-cage induction motor, driving an 83kW d.c. generator and a 6kW, 220V, level-compound-wound exciter. All machines on the motor generator set are naturally ventilated. They are housed in an upstairs compartment in the machinery house with the electric control gear. The generator has two separately excited field windings bridge connected with two resistances. Two magnetic amplifiers are used to supply the field windings, the circuit being arranged for the amplifiers to operate in push/pull. The hoist motor is therefore reversible by making one of the amplifiers predominate over the other.

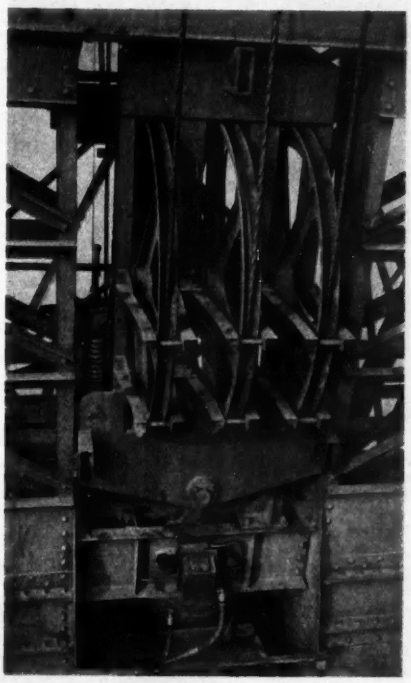
At the instant the hoist controller is moved from the zero speed position, maximum field forcing is applied to the generator to overcome the machine time constant. A voltage feedback signal derived from the generator armature subsequently reduces the degree of field forcing as the generator voltage builds up. Rapid deceleration is achieved by regeneration and a solenoid-actuated mechanical brake is used only for holding purposes. This brake is applied automatically by voltage relays in the main armature circuit after the speed of the hoist has been reduced by regenerative braking literally to zero. This characteristic makes it possible to reduce the size of brake and it also prolongs the life of the brake linings. The brake is made by Elliston, Evans and Jackson, Ltd., and has a 30in diameter drum running at 230 r.p.m. with a maximum braking torque of 6000 lb-ft.

Two bias windings are provided on the magnetic amplifiers to ensure that when the controller is in the zero speed position the outputs of the two amplifiers are matched. These biases require no adjustment after initial setting.

As the mechanical inertia of the hoist system is low, the rapid changes in the generator voltage due to field forcing are translated into rapid acceleration or deceleration of the drive without dangerous overload currents in the armature circuit. The equipment was originally provided with a form of current limit control operating on an additional set of windings on the magnetic amplifiers. In view of the very low kinetic energy, however, it was found possible to dispense with this current limit in practice. In the event of a severe overload due to an obstruction in the way of the grab, an instantaneous overload trip, in the armature circuit of the hoist motor, de-energises an under-voltage relay which applies the magnetic brake and disconnects the supply to the control windings of the magnetic amplifiers, thus causing a rapid deceleration to standstill.

The fact that the driver has complete control over the hoisting motion, coupled with the high speed, enables him to concentrate more on the slewing and luffing motions, the control of which will always be limited by grab swing.

The mechanical hoisting gear is of conventional two-barrel design with a coil clutch and hold brake, both of which are thruster operated under the control of a switch incorporated in the hoist master controller. An electrical circuit is incorporated to ensure that if the driver attempts



Weighing sheaves and load balancing equipment of grabbing crane

to engage the clutch with the closing barrel running above 250ft per minute, the clutch thruster operation is delayed until the speed has dropped to below this figure, and full regenerative braking applied. Full acceleration is then automatically switched in up to the speed dictated by the controller notch in use. This arrangement has proved successful, and in practice the driver makes no attempt to slow up, the slowing and accelerating being left in full control of the automatic equipment. Apart from protecting the clutch equipment, this arrangement also helps to reduce snatch on the ropes. The driver is still able to disengage the clutch at full speed as this does not impose a shock on any mechanism, and is, in any case, essential for quick discharging of the grab.

The layout of the driver's cab, to be seen in one of our illustrations, received considerable attention. To the right of the driver is an Allen West miniature master controller, the handle of which is moved towards the driver for hoisting and away for lowering. A slight sideways movement of the handle disengages the hold barrel from the closing barrel and enables the hoisting and lowering movements to be converted to closing and opening movements respectively. To the left of the driver is a joystick Allen West controller, operating on slew and luff motions.

The original specification for the crane included a foot brake on the hoist motion, and as this brake drum was to be on the second motion shaft, a servo-assisted brake became necessary to reduce the effort on the part of the driver. This requirement was provided by a design by Elliston, Evans and Jackson, Ltd., in which the hoist brake was released by a conventional thruster, but could be reapplied by the foot pedal which bled pressure from the thruster, and gave gradual braking up to maximum torque under full control of the driver. After some experience had been obtained in using the cranes, it was discovered that the control afforded by the hoist mechanism was so efficient that the foot brake was never used and it has been removed.

On occasions the cranes have to handle cargo, and as the requirements for this duty include creep speeds in both hoisting and lowering directions, in spite of large variations in the load, a change-over switch has been fitted. This switch is under the control of the driver and enables him to select hoisting conditions for cargo or grabbing duty. With the switch in the grabbing position, the hoist controller has roughly equal increments in speed for each notch, and the electro-mechanical brake is under the automatic control of the voltage relays referred to above. With the switch in the cargo position, the voltage on the controlling potentiometer for the magnetic amplifiers is considerably reduced, and the magnetic brake arranged to come on immediately the controller is brought to the off position. This reduction in the potentiometer voltage has enabled very slow controlled creep speeds to be obtained, the first notch speed being about 7ft per minute, with a maximum speed of 250ft per minute. These speeds are practically independent of load.

The driver has a foot-operated switch which frees the hold barrel brake when the clutch is disengaged and allows the grab to sink in the material when digging without free hold rope being paid out in advance. This switch is only operative when the hoist controller is in the "open/close" position. In order that the hold rope shall be kept at a slight tension a slipping clutch has been incorporated between the hold barrel and the close barrel.

The general shape of the crane's superstructure was dictated by the desire to use the fewest possible reevings on the counterbalance weight ropes. The arrangement adopted has a twin rope connection between the hoist barrel and the counterbalance weight with three reevings at the weight. The hoist barrel is extended to take the counterbalance ropes. It was assumed in the design stage that it might be dangerous to carry the counterbalance ropes in the same grooves as the hoist ropes, it being felt that under slack rope conditions the hoist ropes would tend to wander along the drum and become entangled with the counterbalance ropes. Largely due to the single reeving and the large drum diameter, practice has proved that this fear was unfounded, and future cranes will probably be constructed with one set of grooves for the two duties. This will reduce the length of the closing barrel by approximately 50 per cent. The runway for the sliding weight is inclined at a small angle to eliminate undesirable rattling, and the weight runs on rollers on the track. A safety gear incorporated in the weight clamps it to the guides in the event of either or both ropes breaking.

Each of the cranes is fitted with a Williams recording weigher, which automatically prints on a paper strip the total net weights discharged from the grab. Automatic compensation incorporated in this equipment allows for the variations in the weights of the ropes with hoisting and deducts the tare weight of the grab. The driver, to obtain a weighing, presses a button which locks the crane out for four seconds. This is long enough for the grab and crane to stabilise and immediately after the weighing the crane is re-energised for work.

The hydraulic load-balancing equipment of the weighing machine and a set of weighing sheaves, taking all three ropes (one holding and two closing) is assembled in the superstructure immediately over the machinery house roof. A further set of three sheaves, mounted on a pivoting beam above the weighing sheaves, takes the ropes from the weighing sheaves to the hoisting drum. This assembly equalises the loads in the

two closing ropes up to comparatively large angles of tilt of the grab.

All sheaves on the crane are of light cast steel construction with roller bearings, the jib and counterbalance sheaves being 4ft diameter, and the superstructure's hoisting sheaves 5ft diameter. As the closing ropes are 3in circumference, the hold rope 3¾in, and the counterbalance ropes 2½in, the ratio of sheave to rope diameter is very large. This was considered necessary in view of the high rope speed of the crane.

The slewing race track and gearing is of orthodox design with live rollers and a pin rack and it is lubricated by a " Brentford " automatic equipment driven from the slewing motor. The slewing motor is coupled to the rack pinion through worm and spur gearing, incorporating a slipping clutch. A very smooth take up of the drive has been obtained by grading the resistors so that a relatively small torque is exerted on the first notch of the controller to take up the slack in the gearing and reduce any hammer blow. The slewing controller has a total of four notches in each direction, although five steps of contactors are employed, the last step following on automatically after the fourth on the last notch of the controller. The first three notches are under direct control of the driver, and give progressive increments in torque under standstill conditions. The last two notches are controlled by voltage relays operating from the rotor circuits.

The luffing machinery is fitted with an Elliston Evans and Jackson, Ltd., two-stage brake, which provides instantaneous removal of braking torque when the motor is switched on, but applies the brake gradually when de-energised. The electrical control gear is in general similar to that for the slewing, but only the first notch is under direct control of the driver. The contactor for the first notch is locked out by a voltage relay operating across the rotor resistor until the plugging current, if any, falls to a low value. The remaining notches are under the control of current relays working from a current transformer in the motor stator.

All the control gear, with the exception of the magnetic amplifier equipment, has been supplied by Allen West and Co., Ltd., and is housed in two cubicles on the upstairs floor of the machinery house.

The crane travels at 55ft per minute on twelve wheels, powered by two 10 h.p. motors controlled from a full current drum controller in the driver's cab. Current is supplied to each crane through a 0·2 square inch, four-core T.R.S. flexible trailing cable, and a " Deco " gravity-operated cable reeling drum. This small size of cable was made possible by the relatively small currents required by the Ward-Leonard hoist mechanism. Power supply for the cranes is taken from eight 300A flush deck plug boxes, designed for easy insertion and removal of the plugs, and arranged so that the plug pins do not take any side pulls from the trailing cables. The tops of the plugs locate in guide rings in the jetty deck, and are fitted with a bead developed by Samuel Williams and Sons, Ltd., which restricts the minimum radius through which the cable is bent irrespective of the position or pull in the cable.

The two cranes have now been in operation for approximately six months, and on a recent cargo of small coal, cycle times of twenty-one seconds were maintained when working overside from ship to barge.

MANUAL OF SCREW THREAD TOOLS.—To provide a useful reference on screw thread tools, Firth Brown Tools, Ltd., Carlisle Street East, Sheffield, 4, has published a 300-page book entitled *Manual of Screw Thread Tools*. It deals in detail with thread production, mainly with the use of screwing taps and chaser dies. Current tap and screw thread nomenclature and definitions are given with descriptions of many of the different types of taps in general use. Information is given on tap design and maintenance, and the most suitable types to use on a wide range of different materials. The causes and remedies for tap failures are discussed and lists are included on tapping drill sizes, with notes on tap lubrication and speeds. Copies of the manual, price 25s., can be obtained on application to the firm.

Automotive Turbo-Charger

A German exhaust-turbine supercharger that has been widely used on diesel vehicles in Europe is shortly to be manufactured in this country. A number of British engines have already been catalogued with this blower, and we give below some details of its application.

ONE hundred and twenty different diesel engines have been adapted to exploit the turbo-supercharger developed by Geratebau Eberspacher, of Esslingen. Five British engines have now been similarly equipped, and early in 1957 production of these turbo-chargers will begin at the East Finchley factory of Simms Motor Units, Ltd. Some of the engines which have been so equipped were recently displayed to us by the licensees; one which was seen running at steady speed on the dynamometer was the Meadows 6 D.C.S.630 engine described in our issue of September 21 last, page 406. A larger six-cylinder Meadows, the 6 D.M.S.970, was on show with a turbo-charger on each cylinder block, the units chosen having the bearing housings water-cooled; this engine with a single Brown Boveri turbo-charger was described on September 23, 1955, page 430. Similar blowers were used on the Rover " Meteorite" (Fig. 2), one immediately to the rear of each exhaust manifold; interestingly enough, two aftercoolers were employed so that although a balance pipe gave equal pressures in each inlet manifold, the temperatures might differ. The charge cooling allowed the power of this engine to be raised from 310 h.p. to 450 h.p. with even greater torque increases at restricted speeds. A third engine with the partly liquid-cooled unit was the Dorman 6KD; this is 14·778 litres in swept volume, but has only one blower. Although the power is raised from 197 h.p. to 237 h.p., a sacrifice of 5 per cent in specific fuel consumption is entailed. Air-cooled superchargers are employed on the indirect injection Perkins R.6, which benefited in efficiency particularly at the higher speeds, and on the Thornycroft KRN 6, which alone, among these engines, showed a blown torque characteristic similarly shaped to that naturally aspirated.

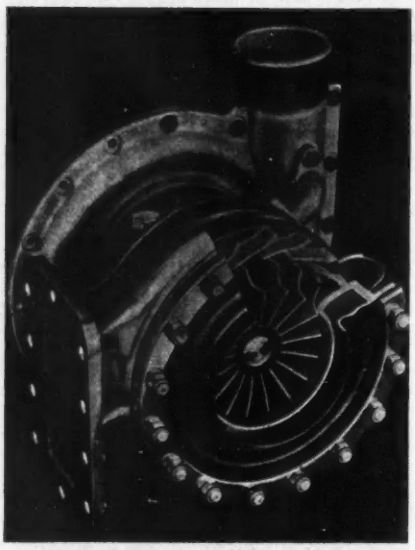


Fig. 1—Supercharger with air-cooled turbine casing sectioned; the nozzle box is divided into two spaces. The duct taking delivery air to cool the turbine rotor can be seen

The supercharger units can rely on air cooling when they are run edge on to the engine cooling air stream, but use a water-cooled bearing housing if the turbine or compressor screens the centre portion of the unit. When the blower is not located in an air stream, a water-cooled turbine casing can be employed.

Full details of the construction and charts of the characteristics of the turbo-charger are not at present available—the units at present in use are all imported—but it may be mentioned

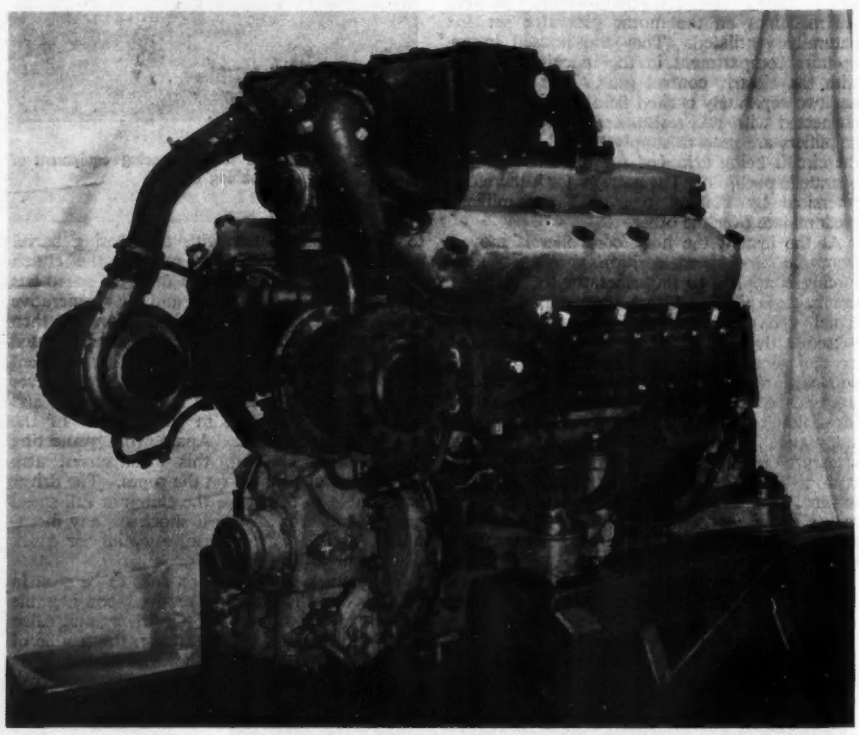


Fig. 2—Two turbo-chargers give the Rover " Meteorite " an output of 450 h.p.; notice the charge cooler on top of each induction manifold and the water-cooled bearing housings

that the turbine and compressor rotors, the former a lost wax casting in austenitic steel and the latter light alloy, are shrunk and bolted respectively on an austenitic shaft ; the assembly totals 2·2 lb and its permissible maximum speed is 38,000 r.p.m. It is carried in two ball bearings, backed by springs to allow them end float in their housings ; it is upon the low inertia and friction of the rotor that the unit relies for response to the rapidly varying loads of automotive duty without the smoke limit being momentarily exceeded. On test, the turbo-chargers are run as gas turbines ; with the compressor intake throttled to run self-sustaining at a turbine inlet temperature of 1200 deg. Fah., a compressor efficiency of 70 per cent is expected, while the turbine efficiency may vary from 80 per cent on a unit matched to a constant speed engine to 75 per cent on an automotive unit. Matching is achieved by variations in the nozzle rings and rotors within the same basic casings, which have a diameter of 11in and a total weight of 37½ lb. The maximum gas temperature acceptable is 1256 deg. Fah.

As in the Buchi turbo-blower, it is expected that there will be a measure of pressure pulse charging, and the exhaust manifold must be tuned to the desired engine speed. The manifolds on display appeared to include small gas passages and impart high momenta to the gases ; although the gas enters the two nozzle boxes in opposite directions, and in one case must have its swirl reversed, there is said to be no appreciable difference in the pressures observed. The division between the two chests can be seen as a kink in the casings in Fig. 2 ; another pattern of casing with three inlets and nozzle boxes was also displayed, and was fitted to the large Meadows. The supercharger is usually supported by the manifold ; the exhaust pipe fits into the light shroud seen in Fig. 1.

The centre of the turbo-charger is filled with air at the compressor delivery pressure, and this air is led to the glands outside the bearings, some of it being allowed to escape along the back of the turbine rotor for cooling purposes. Two discs on the shaft inboard of the bearings dip in the oil, and oil rotating with them is directed into the bearings. It is prevented from escaping by metal labyrinth seals. The lubricant is engine oil ; normally, a reservoir is provided, but a by-pass supply from the engine oil system may be used, excess being returned to the engine.

The compressor is a conventional centrifugal unit with a vaneless diffuser. Delivery is from a volute ; it is found that a markedly assymmetric inlet trunking, when an air-cooled unit is employed, has no adverse effect.

Where an exhaust brake is required, two or three butterflies are fitted in the turbine inlet passage ; the compressor surge that occurs when the brake is opened has no adverse effect.

The Turbo-Charged Engine

The turbo-charger, as stated above, has still to be brought into production in this country. It may be observed, however, that those among the engines referred to which are already catalogued, show distinct decreases in cost per horsepower when supercharged, even when supplied for industrial purposes, i.e. without auxiliaries. Some of the other problems involved in the introduction of exhaust-turbine-driven superchargers were discussed in our account of the Commercial Motor Show. Since it is to be expected that a manufacturer building engines for his own vehicles will be in the best position to meet these problems, it is interesting to study in detail the KRN 6/S engine of Transport Equipment (Thornycroft), Ltd., which is used in the "Big Ben" described and illustrated on pages 430–432, September 21, 1956.

A matter upon which Thornycroft lays great stress is that, although a normally aspirated version is catalogued, the engine, transmission and running gear of the vehicle were designed for the blown output of 200 h.p. The engine is basically a conventional direct-injection 11·33 litres six of compression ratio 16, with the Thornycroft feature of a thermostat to keep the cylinder walls at a favourable running temperature even if the head is running cool. However, the lubricant is circulated through finned tubes in front of the coolant radiator, which, in the

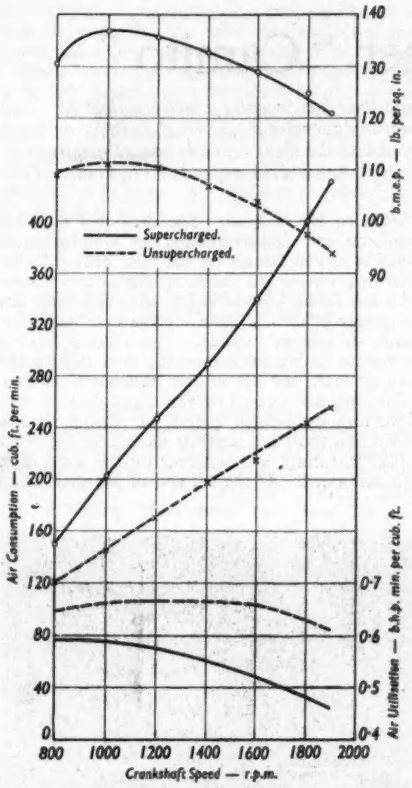


Fig. 3—Thornycroft "KRN 6" unsupercharged and supercharged full rack characteristics

absence of a scavenge pump, run at full delivery pressure. The installation was engineered by Eberspacher, and the matching of the turbo-blower was determined by the necessity for preserving the low-speed torque expected from a truck engine. As can be seen from Fig. 3, the torque is at a maximum at 1000 r.p.m., at which speed it has been increased 23 per cent compared with 30 per cent at the governed maximum of 1900 r.p.m.

The full rack curves, it may be borne in mind, run about 5 per cent below the smoke limit of this engine, and so it can be seen that with the matching chosen the shape of the smoke limited torque curves is little altered. The curve of air consumption against torque, Fig. 4, shows that a 5 per cent increase in output involves barely 1 per cent rise in air flow—the curves at lower speeds are similar in shape—so that the air utilisation characteristics can easily be related to the onset of incomplete combustion. The marked increase in specific air consumption will be observed ; this may be associated with the diminished penetrating powers of the fuel spray in the denser charge. Even were this decrease in air utilisation not enforced by the smoke limit,

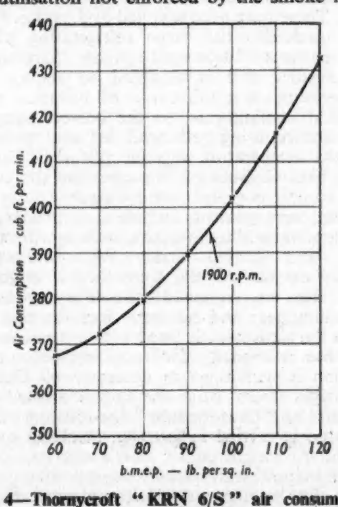


Fig. 4—Thornycroft "KRN 6/S" air consumption at constant speed

it might well be introduced in order that combustion chamber temperatures should not increase in proportion with the engine rating.

It is the increase in available torque, rather than the need to keep the engine spinning, that has prompted the use of closer gear ratios with the supercharged engine. The fact that the auxiliary reduction train is effective on all gears has been exploited to allow a conventional four-speed box, on which first, however, still calls for the long selector travel associated with sliding gear engagements. The gearbox being mounted on the clutch housing, the remote control is clamped to the crankcase. The aforementioned auxiliary box has two reduction and one overdrive ratios on the six-wheel-drive normal control vehicle illustrated previously, one direct and one reduction on the forward control chassis with rear wheels only driven.

The induction system is mounted above the engine, and the cowling comes shoulder high in the forward control cab. When the engine is idling, the noise is that of a normal direct-injection diesel, but increase in fuel summons a howl from the turbo-charger ; the scream of this component under load is most noticeable on first acquaintance, but soon becomes unobtrusive. This noise enables the crew to gain some idea of the blower speed, and it is very noticeable that a sharp movement of the fuel rack with the engine in gear, which cannot be followed rapidly by the air flow, is the signal for an almost abrupt acceleration of the blower. The manner in which, as the engine speed rises through the governor run-down, the turbine becomes quieter, finally being rendered inaudible by the increase in mechanical noise at 2000 r.p.m., illustrates the dependence of the turbine on inlet temperature. The rapid response upward is accentuated by the fact that no boost-sensitive limitation on fuel is employed, so that transient turbine inlet temperatures can exceed the steady state values.

The laden vehicle weighs 32 tons, and the engine is obviously a match for it ; the vehicle can gain speed on obvious adverse gradients in top gear. It is noteworthy that, even below the maximum torque speed, the vehicle does not lose speed unduly quickly, and the fuel-conscious driver can breast crests at 600 r.p.m., although the transmission will then be responding to individual power strokes. An incidental advantage of the supercharged engine is the rapidity of changes, the clutch stop being ignored except on up grades. Clearly, if an unblown engine of the same output was used, the shifts would be markedly slower, while if a similar sized engine was retained, a wider range of ratios would be necessary. (The intervals in the main box are, progressing downwards, 1·66, 1·645 and 1·76.)

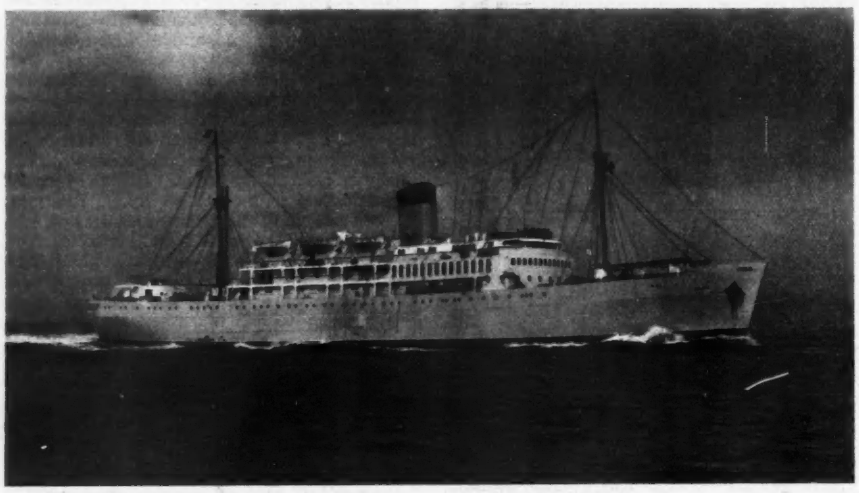
Based on experience with this engine, Thornycroft anticipates that fouling of the turbine blades, with resultant mismatching and dynamic unbalance of the unit, is a problem that has been exaggerated. On an engine in which combustion is consistently good, the blower can be expected to run without attention, other than to its self-contained oil system, for perhaps 100,000 miles, at which stage maintenance on the engine itself might well be required. The rolling bearings have given no trouble whatever in normal usage. It has not proved possible to obtain any improvement in specific fuel consumption, presumably because of the poor efficiency of the radial flow machinery, but normal road results approaching 8 m.p.g. indicate an acceptable combination of engine, supercharger and transmission.

Materials Data Sheets.—To help the aircraft industry familiarise itself with the new "S.500 series" British Standards for steel sheet and strip, the S.B.A.C. has issued an addition to the range of S.B.A.C. Materials Data Sheets. The new schedule, MAT.6—Sheet and Strip, complements the recently revised MAT.1 covering specifications for steel bars and forgings. It provides a quick reference to the complete British Standard range for steel sheet and strip and also to those D.T.D. specifications still available for more specialised requirements. Copies of the schedules and of data sheets MAT.2–5, covering aluminium alloys in the form of sheet, strip, castings, bars, forgings, extruded sections and tubes, are available from the Society of British Aircraft Constructors, Ltd., 29, King Street, St. James's, London, S.W.1, price 1s. per copy, or 6s. per set of six sheets.

Twin-Screw Liner "Camito"

The passenger and refrigerated banana cargo liner has recently joined the fleet of Elders and Fyffes, Ltd., to maintain the company's service to the West Indies. A total of 103 first class passengers are carried and the ship, which is propelled by two sets of geared turbines of 10,500 total s.h.p., has a service speed of 17½ knots.

RECENTLY Elders and Fyffes, Ltd., took delivery of the twin screw passenger and refrigerated banana cargo liner "Camito," which has been built and engined by Alexander Stephen and Sons, Ltd. The ship will join the "Golfito," constructed by the same builders, to maintain a fast service to and from the West Indies. Mainly of welded construction, the liner, which is shown on its trials in our illustration, has a length between perpendiculars of 415ft, a breadth moulded of 62ft, a depth to the upper deck of 34ft 9in, and accommodates 103 first-class passengers in single and two-berth cabins. Two sets of cross-compounded



Passenger and banana cargo liner "Camito"

double reduction geared turbines, developing 10,500 service s.h.p. at 125 propeller r.p.m., give the ship a service speed of 17½ knots.

The fine-lined hull has three complete decks, namely, bridge, upper and main, below which are the lower and orlop decks forward and aft of the machinery spaces. Above the main hull are the promenade and boat decks. There are seven watertight bulkheads and four insulated holds with associated 'tween decks arranged two forward and two aft of the machinery spaces. The double bottom, which is framed longitudinally, is arranged for oil fuel or water ballast. The ship incorporates in its structure a high degree of fire protection and has been built under Method I as laid down by the Ministry of Transport. In place of plywood, "Marinite" has been used extensively for bulkheads and panelling and also the class "A" divisional bulkheads, in which fire-resisting doors have been fitted. The cargo spaces are protected by CO_2 fire-extinguishing and detecting systems, while in the accommodation spaces there is an electric automatic fire alarm and detector system.

Accommodation for the passengers is arranged on promenade, bridge and upper decks in large single and double cabins, many having a private shower, and two special suites at the forward end of the house on the bridge deck. The public rooms are aft in the promenade deck, there being a spacious lounge and ball room forward of which is a smoke room and bar to port and a library and writing room to starboard. All these rooms are panelled in "Marinite" veneered with a variety of woods. Aft of the lounge is the swimming pool and sports deck. The dining room, which can seat 106 people at tables for two, four and six, is well forward on the upper deck, and arranged around the trunked hatch to No. 2 hold. The deck and engineer officers are accommodated in well-furnished cabins in two houses on the boat deck. In the forward house are the deck officers and a suite for the captain, while in the after house are the engineer officers, a suite for the chief engineer, and an officers' lounge. The officers have a separate dining saloon on the port side of the upper deck just aft of the passengers' saloon. The crew are located on the upper deck in one, two and three-berth cabins, all having natural light and there are separate messes for the petty officers, ratings and stewards on the same deck to starboard. At the aft end of the deck is an airing space, while a large recreation room is provided on the main deck just forward of the steering gear compartment. In way of both the passenger and crew accommodation, the ship's sides and decks are protected against the heating effect of the sun by Fibreglass "B" fibre.

General Equipment

The well-equipped galley is on the upper deck just aft of the main dining saloon and, below it, are the main store rooms with a large working entrance associated with watertight doors in the ship's sides. For the cold stores the refrigerating plant consists of belt-driven "Arcton" compressors. These have been supplied by J. and E. Hall, Ltd., and also the cargo refrigerating plant. This consists of two eight-cylinder "Arcton" 6 compressors and is designed to reduce the temperature of a full cargo of bananas, at a specified cooling rate, to the correct carrying temperature, using both machines, and to maintain that temperature with one machine. Centrifugal backward-bladed fans circulate the cargo cooling air over grilled tube coolers.

Safety arrangements include a complement of six aluminium alloy lifeboats, built by Mechans, Ltd., and carried under Welin-McLachlan gravity davits. All the boats have a length of 26ft; five are equipped with Fleming hand-propelling gear and can carry forty-six persons, while the sixth boat is fitted with a diesel motor and has a capacity for forty persons. Subdivision is maintained as necessary by Donkin watertight doors, while the ship is divided into sections by "Dreadnought" fire-resisting doors.

Cargo is carried in fourteen insulated spaces served from eight cooler rooms and the spaces are insulated with resin-bonded "Fibreglass" slabs. For handling there is a complement of eight 5-ton derricks operated by four 5-ton Clarke Chapman electric winches and topping winches. Sunderland Forge and Engineering Company, Ltd., provided the electro-hydraulic windlass and the four electric capstans, two being arranged forward and two aft, and all able to exert a pull of 13,500 lb. The hydraulic unit for the windlass and the motors for the forward capstans are located on the upper deck. Steering is effected by Hastie four-ram electro-hydraulic gear. Thermotank, Ltd., has been responsible for the mechanical ventilation fitted throughout the accommodation and, in addition to the heated air supply, steam radiators are fitted in the public rooms. The navigation equipment includes a Sperry gyro compass, Marconi radio, Decca navigator and Chadburns' telegraphs.

Main and Auxiliary Machinery

The shipbuilder has supplied the propelling machinery, which consists of two sets of cross compounded double reduction geared turbines, of Pametrada design, which develop a total service s.h.p. of 10,500 at 125 propeller r.p.m. Each set has one h.p. ahead turbine and one l.p. ahead turbine, the exhaust end of which incorporates the astern turbine, and underslung from the l.p. casings are the main condensers designed to maintain a vacuum of 28·5in, with sea water at a temperature of 75 deg. Fah. For circulating each condenser there is a Drysdale pump with a capacity of 7500 gallons per hour against a 23ft head. Weir's closed feed system is fitted and includes two 61,000/122,000 lb per hour extraction pumps and two turbo-feed pumps, each with an output of 132,000/172,000 lb per hour against a discharge pressure of 650 lb per square inch; an electro-feeder for harbour duties is able to deliver 21,000 lb per hour. For auxiliary duties there are two 5000 lb per hour feed pumps. There are two three-stage air ejectors, a drain cooler having a surface area of 250 square feet, two glands and ejector condensers and a deaerator, and associated extraction and lift pumps, for use in port, with a rating of 25,000 lb per hour.

Feed heating is arranged in two stages, 122,000 lb of feed per hour being raised from 136·6 deg. to 255 deg. Fah. in the l.p. heater and from 225 deg. to 318 deg. Fah. in the h.p. feed heater. To satisfy boiler and domestic requirements an evaporating and distilling plant is installed, there being two double-effect evaporators and two distilling condensers, all rated at 12,300 U.S. gallons per hour, and associated equipment, such as pumps, air ejectors and fresh water filters. There are two lubricating oil purifiers and heaters, one diesel oil purifier and heater, and one diesel lubricating oil purifier and heater, all of Alfa-Laval manufacture, and all rated to handle 300 gallons per hour with the heaters able to raise the temperature from 100 deg. to 180 deg. Fah. The four Serck lubricating oil coolers can each reduce the temperature of 9500 gallons per hour from 135 deg. to 110 deg. Fah. and the system includes two banks of four Vokes strainers on the discharge side of the Drysdale lubricating oil pumps, and magnetic strainers on the suction side.

Most of the auxiliary pumps are of Drysdale manufacture and besides those already mentioned, this company has supplied two lubricating oil cooler circulating pumps and a bilge and ballast pump, each rated to deliver 95 tons per hour against a 45ft head. The two fire and sanitary pumps have a capacity of 80 tons per hour against a head of 120ft, while the emergency bilge pump can deliver 95 tons per hour against a 65ft head, and the fire and bilge pump the same quantity against a head of 120ft.

Steam is raised in three Babcock and Wilcox single pass sectional header, water-tube boilers at 510 lb per square inch and 750 deg. Fah. at the superheater outlet. Bailey automatic combustion control is fitted and the boilers operate under Howden's forced draught system, there being a fan of 14,000 cubic feet per minute capacity for each boiler. Fuel oil is handled by a 55 tons per hour transfer pump and there are two Babcock oil fuel burning installations, each dealing with 9000 lb per hour. To provide steam to the low pressure system for hotel services and fuel heating, there is a Cochran

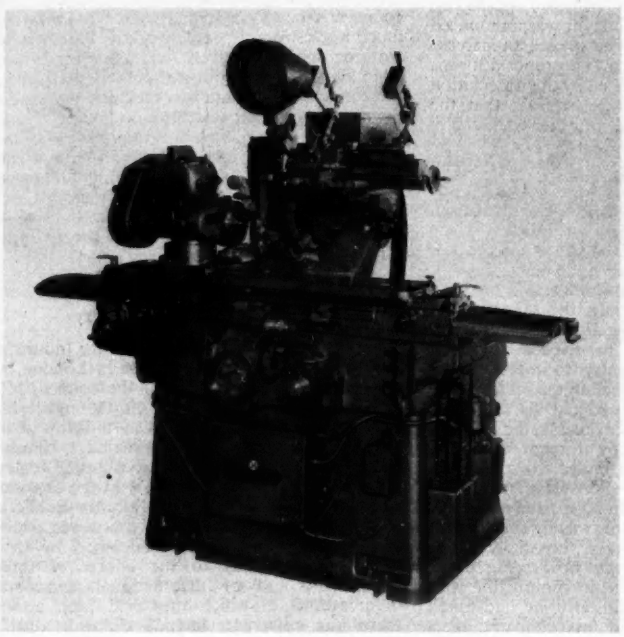
boiler, fitted with Todd oil burning equipment, which is rated at 3600 lb per hour from 50 deg. Fah. at 100 lb per square inch. At sea the low power steam is provided by a Weir steam generator of 5000 lb per hour capacity.

For the ventilation of the machinery spaces there are six Axia fans, two supply fans for the engine-room and two for the boiler-room, each rated at 25,000 cubic feet per minute, and two engine room exhaust fans having a capacity of 30,000 cubic feet per minute. Electrical demand for lighting, domestic services and auxiliaries is met by two 500kW, 200V d.c. self-contained turbo-generators which are located in the wings at the aft end of the engine-room. There is also a 480kW diesel-driven generator on the centre line. All the electrical gear has been manufactured by W. H. Allen, Sons and Co., Ltd. For emergency purposes the ship is provided with a 75kW generator driven by a "National" oil engine and mounted in a house at the aft end of the bridge deck.

Circular Form Tool Grinding Machine

A HIGH-PRECISION circular form tool grinding machine now being made by A. A. Jones and Shipman, Ltd., Leicester, is designed to grind work up to 8in diameter, 12in long, and admits components up to 24½in long between centres. The new machine, shown in the accompanying illustrations, incorporates a number of means designed to speed and facilitate the production of the more difficult classes of cylindrical formed work.

It has a heavy cast bed, on which are mounted, at the usual right angles, the wheelhead slideways and the main table slideways. The long wheelhead slide projects into recesses under the main table and is mounted on anti-friction bearings. Two wheels are mounted, one at each end of the spindle, in the swivelling wheelhead, with which angular settings can be made by reference to a graduated indicating scale and a vernier. The spindle is driven by belt from a 0·95 h.p. motor and has two speeds of 2600 and 3500 r.p.m. for external grinding. For internal grinding purposes a drive with two speeds of 12,000 and 18,000 r.p.m. are available.



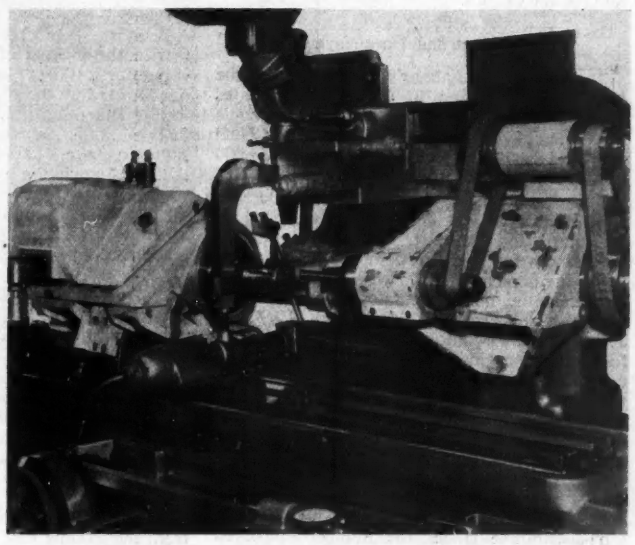
Circular form tool grinder with pantograph wheel truing equipment and optical projector

The table has a longitudinal traverse of 22in and the wheelhead a cross feed adjustment of 10½in. The table and the wheelhead are fitted with similar three-speed feeds. In each case the feed mechanism consists of the usual screw and nut, and at the front of the machine is a control box governing the rotation of the feed screw at three speeds. A fast feed handwheel, directly coupled to the feed screw, is brought into use by pulling out its handle, which automatically disengages the other two finer feeds. The rate of movement of the wheelhead or table is then ¼in per revolution of the handwheel. When the handle is pushed in flush with the front of the main handwheel it is automatically removed from possible disturbances, and the movement engages a fine feed to the nearest 0·10in. This is the setting for normal feed used by the operator for control purposes. A further fine feed can be engaged by a friction clutch arrangement, which enables the feed to be controlled from a small knob, having a wheelhead control rate of 0·001in. reduction in diameter per revolution, and graduated in large divisions showing 0·0001in. reduction in diameter. With the aid of this combination of controls the position of the wheel is always under the full control of the operator.

To supplement the graduations on the feed dials there is provided a system of secondary references using standard gauge bars giving combinations of lengths of 1in, 2in, 3in or 4in. These bars are used in conjunction with a 1in micrometer, settable and readable to 0·001in, in conjunction with a dial indicator. This system is similar to that used in jig boring practice, and with it the position of the wheelhead slide can be ascertained and repeated accurately. The combination of wheelhead slide and the table slide controls gives the machine a system of rectangular co-ordinates equivalent to that found on the normal jig borer, the setting accuracy of which is supplemented by the anti-friction mounting of both slideways.

The workhead can be arranged for either live or dead centre grinding and its spindle is driven by a ½ h.p. motor through a belt or cone pulleys giving six speeds from 30 to 415 r.p.m. A platform at the rear on the wheel support column is provided for the mounting of a "Diaform" pantographic wheel truing equipment. A bracket on which the equipment is mounted is arranged for independent upwards feed and a short length of sideways movement towards the wheelhead. With this arrangement the wheelhead slide can be moved to its rear position to set the wheel over the pantographically controlled truing diamond or diamonds. With the wheel in this position a profile copied in reduced ratio from a template attached to the pantographic truing unit can be formed on the underside of the wheel. The wheelhead can then be moved in towards the workpiece to present the wheel to the work. This truing operation may be performed and repeated without disturbing the axial position of the work or removing it from its supports.

The optical projection equipment to be seen in our illustration can be provided to facilitate the grinding of profile work and with it the contour of the work can be checked and measured using the micrometer mounting slides. This projector has a 0·3in field with a thirty times magnification. It is supplied with standard graticules and special graticules can also be supplied to match the form produced by the template on the pantographic slide. The machine can be arranged for either wet or dry grinding and its equipment includes a dual system of coolant nozzles and means of fitting a dust extracting device.



Grinder fitted with internal grinding head and a form relieving attachment

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

ROUND HARD DRAWN BRASS WIRE FOR SPRINGS

No. 2786 : 1956. Price 2s. This standard was requested by the Coil Spring Federation Research organisation, following on joint discussions with the Brass Wire Association. It specifies requirements for one grade of wire only, the composition of which complies with that designated CZ 107 in a schedule of wrought copper and copper alloys now in course of preparation.

LEADED BRASS STRIP FOR USE IN THE MANUFACTURE OF PARTS FOR CLOCKS, WATCHES AND FOR OTHER INSTRUMENTS

No. 2785 : 1956. Price 5s. This standard gives requirements for three different compositions of brass with varying lead contents corresponding to alloys designated CZ 120, CZ 119 and CZ 118, in the schedules of wrought copper and copper alloys now in course of preparation. All the materials specified are suitable for clock, watch and other instrument components and are satisfactory for blanking, drilling, gear cutting and mechanical engraving. Four grades of tolerance are included for each material, the one to be selected depending upon the application for which the strip is intended.

Appendices to the standard deal with dimensions of tensile test pieces and grain sizes, and include a series of photographs reproduced by courtesy of the American Society for Testing Materials.

Industrial and Labour Notes

Overseas Trade

The Board of Trade's provisional figures about overseas trade in November show that the value of the United Kingdom's exports was £291,800,000. This was only £3,100,000 below the record figure achieved in October, when there were twenty-eight working days. In November, the number of working days was twenty-six. The Board says that, in November, the United Kingdom's exports were 11 per cent above the average for the first ten months of the year. The value of imports in November was £322,800,000, which was £31,500,000 below the October figure, and 1 per cent below the average for the first ten months of the year. But the Board of Trade points out that, in the latter part of November, imports into this country were reduced by delays in the arrival of ships diverted round the Cape. Re-exports in November, at a value of £14,800,000, were the highest this year. The excess of imports over total exports was, therefore, £16,300,000 in November, which was nearly £36,000,000 below the monthly average for the first ten months of the year.

Employment and Unemployment

The Ministry of Labour's latest report on the employment situation in Great Britain states that at the end of October the number of people in civil employment was 23,051,000 (15,247,000 men and 7,804,000 women). This was 33,000 less than at the end of September.

The decline in employment during October was to a large extent seasonal, occurring in agriculture and transport. These two industries were employing 37,000 fewer people in October than in September. In the manufacturing industries the number employed increased by 11,000 during October to a total of 9,265,000. There was an addition of 5000 to the labour force of the engineering, metal goods and precision instruments group, making the total at the end of October 2,804,000. In vehicle building the labour force dropped by 1000 during October to 1,220,000, compared with 1,252,000 a year earlier. Other employment changes in October noted in the Ministry's report include a drop of 10,000 in the number at work in building and contracting, making the total 1,506,000; in the distributive trades the number employed increased by 17,000 to 2,877,000.

A statement by the Ministry on unemployment says that on November 12, there were 264,578 people registered as out of work, compared with 254,073 registered on October 15. The November total included 11,668 who were described as temporarily stopped and 252,910 who had been unemployed for more than eight weeks. The statement also says that in the eight weeks ended November 14, the employment exchanges in Great Britain filled 313,000 vacancies, and that the number of vacancies notified but unfilled on November 14 was 300,000. That was 18,000 less than on October 17 and 88,000 less than a year ago.

Employment and Fuel Restrictions

Last week, a number of questions were asked in Parliament about the possible effect on employment of oil fuel restrictions. In reply to them, the Minister of Labour, Mr. Iain Macleod, said that reports had been received that about 40,000 workers were at present on short time and about 1500 had been declared redundant as a result of the oil fuel restrictions. Most of those workers were in the motor vehicle and accessories industries.

The Minister went on to say that the restrictions had been designed to cause as little disturbance to employment as possible, but some "further effect" was to be expected, particularly in motor vehicles and accessories and road haulage. He hoped that there would be full consultation between employers and workers about those developments with a view to minimising difficulties and avoiding disputes. The Minister added that the services of his department were available if differences arose which could not be settled through the recognised machinery.

Railway Wages

On Thursday of last week, it was announced that the Railway Staff National Tribunal had recommended a 3 per cent increase in the wages of footplate men employed by British Railways. Originally, the Associated Society of Locomotive Engineers and Firemen lodged a claim for a 15 per cent increase, a claim which was rejected in the preceding stages of negotiation. The tribunal is the final stage in the negotiating machinery, but its recommendations following arbitration are not bound to be accepted by either side. The suggestion made by the tribunal was that the 3 per cent award should become effective in the first pay week after November 26. At the time of going to press, no official declaration has been made as to whether the award is acceptable.

Another wage claim for railway workers is still in the process of negotiation. This claim is one for a 10 per cent increase which has been put forward by the National Union of Railwaymen. The third railway union, the Transport Salaried Staffs Association, has also decided to submit a claim. Last Monday it was announced that the Association proposed to seek an increase on behalf of its members. The proposal means the reversal of a decision taken by the Association about two months ago, when it said that the time was not opportune for a further wage claim.

Oil Tankers

The Minister of Transport and Civil Aviation, Mr. Watkinson, was asked on Monday if he would give an estimate of the size of tanker fleet required to guarantee an adequate flow of oil to this country when it was necessary to take the Cape route. In his reply, the Minister said that a fleet of tankers aggregating about 7,000,000 tons deadweight would be needed to bring sufficient oil to this country to meet normal demands. This assumed that all the oil imported from the Middle East was routed via the Cape. The present fleet of tankers available, the Minister continued, including many foreign ships on charter, probably totalled under 5,000,000 tons deadweight. The best short-term means of making good the loss of tanker capacity resulting from the haul round the Cape was by transferring tankers to shorter voyages, especially those across the Atlantic, as was now being done. The Minister also said that, in conjunction with the First Lord of the Admiralty, he had taken steps to speed the repair and turn round of tankers during the present shortage, in order that the greatest possible use could be made of existing ships.

National Institute of Industrial Psychology

The Department of Scientific and Industrial Research has agreed to make an annual grant to the National Institute of Industrial Psychology for the next three years toward the cost of its programme of research. The conditions, it is stated, resemble those attached to the grants made by the D.S.I.R. to industrial research associations in that the grant, up to a maximum of £8000 a year, is related to the amount of grant-earning income in the form of membership subscriptions and special contributions toward the general research programme which the Institute can raise from industry. In view of the importance of human factors in productivity, the D.S.I.R. has in recent years extended its interest to the scientific study of human as well as technical problems. It may be recalled that the National Institute of Industrial Psychology was founded in 1921 in order to increase scientific knowledge of the factors bearing on the health, happiness and effectiveness of people at work. Its activities are of three kinds, namely, the dissemination of information, sponsored research and advisory work, and research on topics of interest to all industry and concerned with the basic problems of people at work. With this new recognition of the value of its work and the prospect of additional support from industry which it offers, the Institute says that it is planning a more comprehensive programme of research than has hitherto been possible.

Since the war, the Institute has undertaken research projects sponsored by the Human Factors Panel of the Committee on Industrial Productivity and others financed by the Medical Research Council or from counterpart funds derived from United States economic aid. These projects have included a study of the operation of various forms of joint consultation; a survey of practices concerning the status, selection and training of foremen; an inquiry into the human problems created by repetitive work, and studies of training factory operatives for semi-skilled jobs. The Institute says that in all its work it is seeking ways by which the individual can be fitted to his job, and the job to the individual, so that people may become better adjusted to working life and therefore happier, healthier and more effective. It has been repeatedly said in recent years that the problem of productivity in this country is largely a human one. It is not so much a question of people working harder as of working more effectively and of being ready, from the managing director to the shop floor, to accept new ideas and new methods. Attitudes of people to their working lives are largely coloured by the relationships they have with the other members of the organisation with whom they work. These do not depend only on human qualities of sympathy and understanding, but are related to all the circumstances in which work is carried out. The new grant by the D.S.I.R. is to be used for research on these issues.

Human Relations in Industry

At the annual general meeting of the Industrial Welfare Society, which was held in London on December 6, the chairman of the council, Mr. H. H. Bagnall, commented on the noticeable progress in human relations in industry since 1945. In the immediate post-war days, he said, the movement to bring about a better understanding of day-to-day relations in the factories and other workplaces was largely due to the efforts of personnel officers and a few executives, whose advocacy was not always welcomed by their colleagues. Thanks to the efforts of those individuals, and of the national and local organisations in which they had been active, there was now, Mr. Bagnall claimed, a wide acceptance of the principles which had been advocated, and to-day's picture, he thought, was very encouraging.

Mr. Bagnall went on to say that a large section of industry had been concerned with management and supervisory training for some years. The training schemes had placed special emphasis on personnel policy and "man-management," and, as a result, the work of personnel departments was now seen in better perspective as an essential service organisation in an enterprise. That relationship of the specialist departments to executive responsibility, Mr. Bagnall suggested, enabled managers and supervisors to give a right and necessary lead in promoting sound day-to-day relationships. As technological advances were made in industry, he added, managers at all levels would need to give more and more attention to the problems of achieving real understanding and co-operation at work. The progress made during the past ten years augured well for the future of British industry, and the Industrial Welfare Society, Mr. Bagnall remarked, could be proud of the contribution which it had made.

Fourth Chemical, Rubber and Plastics Exhibition at Paris

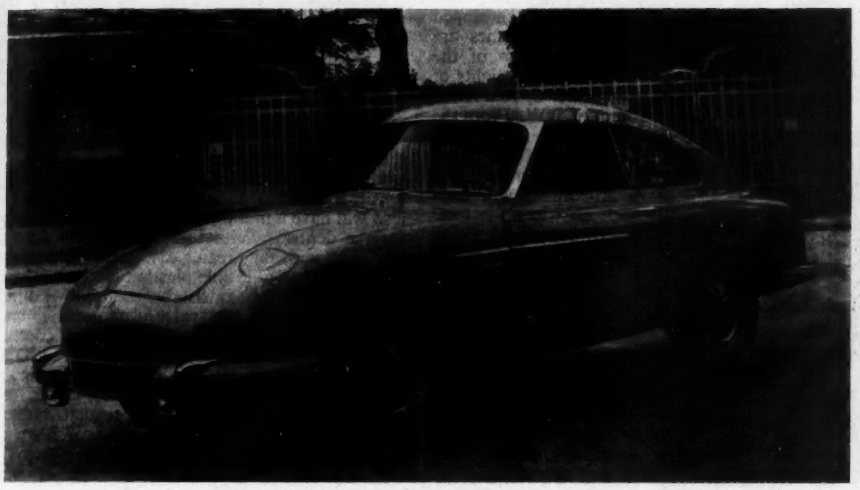
THE fourth Salon de la Chimie-Caoutchouc-Matières Plastiques was held in Paris from November 22 to December 3. In conjunction with this event there was held the twenty-ninth International Congress of Industrial Chemistry and the first European Corrosion Congress (November 19 to 24), the European Conference on Chemical Engineering (November 22 to 24), and the Paris Technical Meetings (November 25 to 30). The exhibition was visited by over 300,000 people, while an estimated 6000 scientists and engineers attended the congresses and technical meetings.

The Salon de la Chimie, which was first held in 1951, constitutes the largest international chemical exhibition of the year. In 1954, there were 850 exhibitors from nineteen countries, with a stand area of 25,000 square metres, while this year the number of participating firms rose to 1100, covering an area of 40,000 square metres, of which 353 were foreign firms from nineteen countries. Of the total area some 7000 square metres were devoted to rubber and plastics, and 12,000 square metres to apparatus and machinery. There were 700 French exhibitors, 132 from West and East Germany, 60 from Great Britain, 59 from the U.S.A., 30 from Canada, 18 from the Netherlands, 14 from Switzerland, 12 from Italy, 8 from Sweden and smaller numbers from Belgium, Denmark, Austria, Hungary, Bulgaria, Saar, Chile, Liechtenstein and Norway. Canadian participation was organised by the Government of Canada and showed the development of the chemical and paper industries.

Canadian chemical production has shown a sixfold increase since the war, passing from a value of 160 million dollars in 1939 to 376 million dollars in 1946, and exceeding 1000 million dollars in 1955. Of particular interest was the exhibit of Polymer Corporation, Ltd., which has a factory at Sarnia (Ontario), built to supply all Canada's requirements of rubber. Coming into production in 1943, the plant produces GRS and butadiene-acronitrile rubbers, rubbers with high styrene content, and butyl rubber. It is the only factory of its kind in the world which is completely integrated, i.e. which itself produces the raw materials for most of its products. Present output exceeds 100,000 tons per annum.

The Commissariat à l'Enérgie Atomique (CEA) presented a survey of the fissile materials used in atomic piles, as well as of the moderators, and special high-purity metals and alloys required in this class of work. The principal physical and chemical characteristics of uranium, thorium and plutonium were shown on displays, as well as models of the concentration plants which have been constructed or are under construction, near the mineral deposits of the Saône et Loire and Vendée. A flow sheet showed the production process of the factory at Le Bouchet where pure metallic uranium for the whole of the French atomic programme is produced from ores and concentrates obtained from the French deposits. The metal is delivered by the factory in the form of ingots which have to be shaped into rods of the sizes required for the various reactors. A flow sheet and model of the Marcoule plutonium factory were also on view. Another model showed the thorium plant which is in process of being built at Le Bouchet and which will treat the Madagascan uranothorianite ores.

Out of the abundance of exhibits, only a few can be singled out here for special mention. The sterilisation of foodstuffs by means of the radiation from fissile by-products was shown for the first time in France. A large autoclave for extreme pressure, for use in artificial diamond research, formed the subject of another exhibit. Progress in fabrication of plastics was evidenced by an industrial fan built entirely of plastic material, with inner and outer diameters of the spiral of approximately 180cm and 200cm respectively. A model presenting the sulphur plant at Lacq was also on view. This plant will, when completed, extract about 70,000 tons of sulphur per annum from the natural gas found in that region, a tonnage which will be sufficient to supply one-third of the total French requirements which at present have to be wholly imported. Among recent developments shown were a corrosion-resistant steel for use in this plant which has an endurance of several months, compared with five days for the steel previously available for this application. Thixotropic paints were another development; these paints become liquid under the brush, but solidify at once when the pressure is released. A great variety of fibre-glass reinforced plastics was shown, including complete hulls of motor boats, An example of this class of work is the plastic car body (see illustration), made by Thomson from "Textiglass" fibre (P. Genin et Cie).



The body of this D.B. car by Thomson is made from glass fibre reinforced plastic

The European chemical industry employs a total of some 1,350,000 people, and has a turnover of 13,000 million to 14,000 million dollars. Investments last year reached about 1100 million dollars, or approximately 2·8 per cent of the total investments. Compared with 1954, last year's production showed an increase of 11·5 per cent (U.S.A., 13 per cent). This represents a certain slowing down compared with the preceding years, which averaged 14 to 15 per cent, but is still superior to that of the industrial and agricultural sectors.

Most spectacular progress has taken place in certain organic branches, e.g. the output of the petrochemical industry, in terms of tons of carbon, has doubled between 1953 and 1955, and investments are expected to increase by 150 per cent between 1955 and the end of 1958. Synthetic rubber production will, it is thought, reach an annual capacity of 185,000 tons by the latter date. Plastics and synthetic detergents increased by 23 and 25 per cent respectively during the period 1953–55; the output of dyestuffs, however, has shown a slight tendency to fall since last year. European chemical exports at present run at 18 to 20 per cent of production. The accompanying tables give the O.E.E.C. export and import figures for 1954 and 1955 :—

TABLE I—*Chemical Imports and Exports of O.E.E.C. Countries (Millions of U.S. Dollars)*

	Member countries and overseas dependencies	Dollar area	Other countries	Total
Imports :				
1954 ...	1,087,095	299,727	137,723	1,524,545
1955 ..	1,221,624 (+12%)	350,212 (+17%)	154,963 (+12%)	1,726,799 (+13%)
Exports :				
1954 ..	1,369,216	236,034	821,710	2,426,960
1955 ..	1,477,222 (+8%)	256,290 (+8%)	952,437 (+16%)	2,685,949 (+11%)

Of the total exports, 43 per cent went to member countries, 12 per cent to overseas dependencies, 10 per cent to the dollar area, and 35 per cent to other countries.

French chemical production in 1955 achieved a turnover of nearly 800 milliard francs. The output in some key categories of production is shown in Table II :

TABLE II—*French Production of Heavy Chemicals in 1955 (Tonnes)*

Sulphuric acid (approximately)	1,500,000
Chlorine	170,000
Ammoniac (nitrogen content)...	430,000
Methanol	25,000
Methanol derivatives :	
Formaline	12,000
Phenol...	25,000
Acetone	24,000
Synthetic detergents...	120,000
Plastics	102,000

The French chemical industry employs about 210,000 people. The chemical sector comprises some 4000 undertakings, of which 110 account for half the total turnover, and 10 for one-quarter. The industry's structure is therefore somewhat similar to that in the U.S.A. (Du Pont de Nemours, 8 per cent; three principal firms together, 15 per cent), but different from that of Great Britain, Germany and Italy.

Third German Tin Conference

Successful experiments in this country to develop a new bearing metal to carry the heavier loads demanded by modern diesel and similar engines were described by Dr. E. S. Hedges, Director of the International Tin Research Council, at the third German Tin Conference, which was held recently in Düsseldorf. Although, Dr. Hedges said, for a whole century Babbitt's tin-rich alloy proved satisfactory for bearings, in the last quarter of a century the considerably greater loads to which bearing surfaces are subjected in some kinds of machinery put more strain on the Babbitt alloys than they are able to endure. A new bearing metal was sought and the aim was, by combining softness with fatigue strength, to make an alloy of tin which could be used with an unhardened shaft under a heavy load.

Dr. Hedges described experiments made at the Tin Research Institute, Greenford, with aluminium-tin alloys, and said that the addition of a small amount of copper was found to improve the alloy's fatigue strength. Laboratory tests on alloys containing 20 or 30 per cent of tin and 1 per cent of copper showed that these were a substantial improvement over the Babbitt alloy. Many service trials in standard engines, both at the bench and on the road, had been completed and the results had been excellent. One of the leading manufacturers of bearings in England

was now manufacturing steel-backed aluminium-tin bearings containing 20 per cent tin.

The Düsseldorf Conference, which was attended by scientists, metallurgists and engineers from all parts of Western Germany, heard Mr. W. R. Lewis, Assistant Director, Tin Research Institute, speak on "Problems of Soft Soldering," and Dr. E. C. Ellwood, the Institute's Chief Metallurgist, describe the new method of continuously casting bronze developed at the Institute.

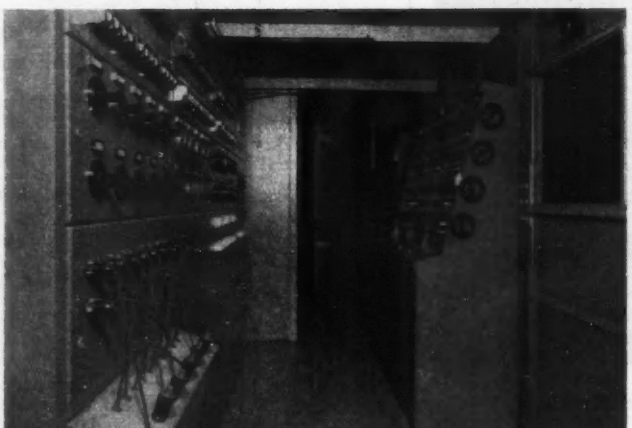
The Conference, which was under the presidency of Dr.-Ing. G. Schwietzke, ended with the showing of a German film "The Charm of Pewter," illustrating the manufacture of pewter in German works.

Stage Lighting at the Düsseldorf Opera House

A novel method of stage lighting developed by Siemens-Schuckertwerke A.G., Erlangen, German Federal Republic, has been installed at the Opera House, Düsseldorf. Our first illustration shows the central control panel from which, following his score, the lighting engineer puts into operation the various effects of illumination and colour. As may be seen from Fig. 1, the control panel comprises a number of levers by means of which the intensity of each light can be adjusted from 0 to 100 per cent, according to the position of the lever on its circular scale. Since in many instances a number of levers have to be operated simultaneously, e.g. in order to imitate a sunrise or the approach of a thunderstorm, each lever can be connected by means of two magnetic couplings to a common motor-driven shaft. In this way, one or more levers can be driven forwards or in reverse, the full movement taking between one second and fifteen minutes. These drive shafts can in turn be joined into groups, so that each group can be controlled by a single master lever. Thus several separate circuits can be controlled by means of a single lever.

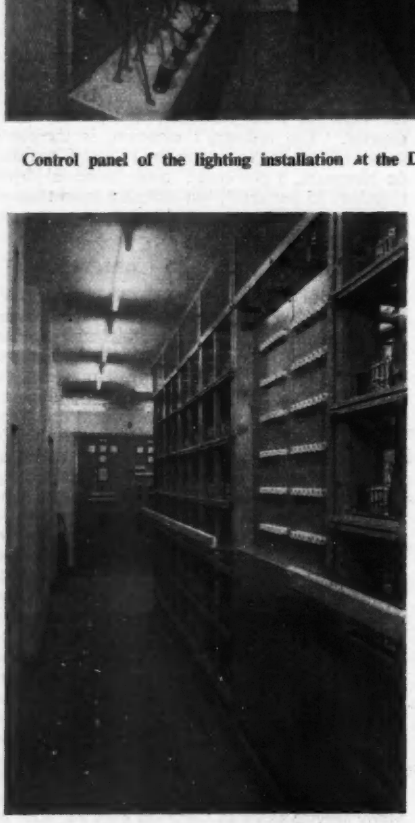
From the master control panel—which is arranged by the side of the stage in such a position that the lighting engineer obtains a good view of the stage itself—a number of low tension control cables lead to the cellar two stories below, where the transducers are housed. This is stated to be the first occasion that transducers have been used in such an application. Each unit comprises a transducer, consisting of an iron core with two windings, one for the operating current and one for the control current, and, in addition, a rectifier and resistors; all these components are mounted on a common frame.

The transducers have been specially developed for this application. Their characteristics are independent of the load, so that each of the 180 circuits can have connected with it lights of any power up to a maximum of 5kW. From the transducers, current is supplied to the stage lights by means of multi-core cables, each with six wires, the total length of cable being 6km. Using these cables in place of twin-conductor cables leads to a considerable saving in space and cost of installation. Spotlights are mounted on seven frames which can be raised or lowered. In addition provision is made for spots for lighting the front of the stage. They may be plugged into any of the 150 sockets which are provided on the stage itself and in the gallery.



Control panel of the lighting installation at the Dusseldorf Opera House

Total installed capacity at the Opera is 500kVA but a later extension to 700kVA is possible. The mains transformer and the seven-section switchboard which distributes the current to the house and stage are situated near the transducer room. Provision has been made for the addition at a later date of a producer's control desk which would allow adjustments to be made from a position in the auditorium. Another possibility is the use of stored lighting programmes which could be pre-selected and put into operation at the correct speed when required by the movement of one lever.



Transducer racks for the dimming control of the stage lighting

Compressed Air Dental Drill

At the thirtieth Paris International Dental Session, a demonstration was given of an air-turbine-driven dental drill. Its speed of up to 50,000 r.p.m. is well above that of conventional drilling equipment, which operates at between 1000 and 12,000 r.p.m. The drill is manufactured by Atlas Copco, Stockholm.

The efficiency of diamond instruments and tungsten carbide burrs, now available, increases with speed, and only very light pressure is required—both important factors in reducing vibration and consequent discomfort. The pneumatic dental drill is said to require only about one-thirtieth of the pressure necessary with existing drilling equipment.

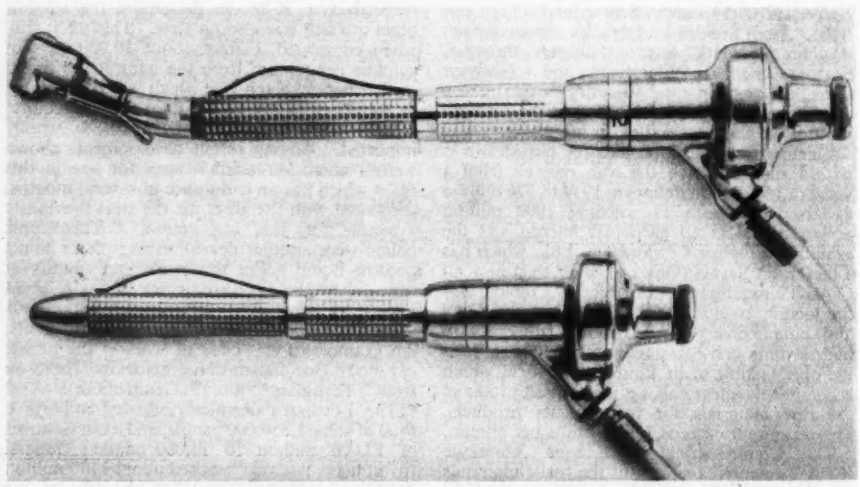
Development of an air-driven dental handpiece which would run at high speeds with manual control was begun in 1948. The design has been kept as simple as possible; apart from the housing and control spring, components in the handpiece number eight, including the bearings.

It is stated that with the Swedish machine there is less tendency to slip and that the elimination of the foot pedal and cord drive ensures more sensitive control. Elimination of the foot pedal also will have a marked effect in reducing fatigue for the dentist. With this machine the dentist can work with far greater ease as the handpiece is connected to a flexible plastic tube.

The equipment consists of a control unit, including a reducing valve, manometer and cut-off cocks and one straight and one contra-angle handpiece. The air turbine is built into the handpiece unit. Power is supplied by a reciprocating compressor fitted with a 1½ cubic feet air receiver. The compressor is regulated automatically, the motor cutting out at a pressure in the receiver of about 8 atmospheres.

A thin rubber tube carries air to the control unit, where it passes through a valve system and drives the turbine at a top speed of 140,000 r.p.m. A specially designed reduction gear, fitted between the turbine and shaft, keeps the maximum speed of the burr to 50,000 r.p.m. A light flow of air passes through the handpiece, cooling the bearings and preventing drillings and saliva from being drawn into it.

The speed is controlled by a spring fitted to the outer casing of both kinds of handpiece. Light finger pressure on the spring releases the brake on the air turbine.



The pneumatic dental handpieces are driven by a built-in turbine rotating at 140,000 r.p.m. By means of gearing the speed of the diamond or tungsten carbide burr (not shown) is reduced to 50,000 r.p.m. Control is exercised by pressing the spring shown

National Metal Congress and Exposition

BY OUR AMERICAN EDITOR

No. I

THE 38th National Metal Congress and Exposition was held in Cleveland, Ohio, from October 8 to 12. As in previous years, it was sponsored by the American Society for Metals, the American Welding Society, the Institute of Metals Division of the American Institute of Mining, Metallurgical and Petroleum Engineers, and the Society for Non-Destructive Testing. Some 450 companies engaged in either the production, treatment or fabrication of metals gave displays and demonstrations of their products or services at the exhibition, which was held at the Clevelend Public Auditorium. Over the years, the Metal Show has continued to become ever broader in its coverage of the metals and metal working field, and gone are the days when it was concerned mainly with the heat-treatment of steels. This year there was again a strong accent on the fabrication and application of some of the more recently developed metals such as titanium, zirconium, magnesium and tantalum. Among the trends to be noticed at this year's Metal Show were an increasing variety of radiography equipment using radioactive isotopes and particle accelerators as sources of energy ; greater uses of ultrasonic techniques in the fields of non-destructive testing, metal cleaning and metal joining ; an accent on automatic inert atmosphere arc welding equipment ; and a growing popularity of vacuum melting furnaces and other vacuum processing equipment.

World Metallurgical Congress

It was announced at the National Metal Congress that a 2nd World Metallurgical Congress would be held in Chicago from November 2 to 8, 1957. It is expected that the attendance from abroad will be similar to that at the first congress in Detroit in 1951, when 550 conferees came from thirty-three foreign countries. The participants should be technologists actively engaged in some phase of the metals industry. They should be metallurgists, engineers, scientists, management personnel, production executives, sales engineers or editors of technical journals in the metal producing and fabricating industries, both ferrous and non-ferrous. Participants may attend individually or may be official representatives appointed by industrial firms, by governments, by technical societies, by trade associations, and by research and educational institutions in the metals field.

The conferees should meet in New York City not later than October 19, 1957. Each delegate will indicate in advance at the time his application is filed a choice of one of nine groups according to his predominant interest. Each of these groups will then proceed on a guided tour for two weeks, during which important works, institutions and operations will be visited and local conferences held. On arrival in Chicago on November 2, the last eight days of each tour will be spent at the National Metal Congress and Exposition and sessions of the Second World Metallurgical Congress convening in Chicago.

The nine groups established by the organisers of the Congress are as follows : (1) steelmaking and refining ; (2) non-ferrous refining and fabrication ; (3) ferrous fabrication (machining, forming, finishing) ; (4) heat-treatment ; (5) welding and jointing ; (6) inspection and testing ; (7) management problems in the metals industry ; (8) education and research (private industry, government bureaux, educational institutions, and foundations and research institutes) ; (9) metallurgical aspects of atomic energy. Notification of interest in participating in the Congress should be sent to Mr. William H. Eisenman, secretary, American Society for Metals, 7301, Euclid Avenue, Cleveland 3, Ohio.

Vacuum Melting

The 50 lb " CVC " vacuum induction melting and casting furnace which is shown in Fig. 1, and was exhibited at the stand of the Consolidated Vacuum Division, Consolidated Electrodynamics Corporation, Rochester, New York, is representative of current American practice in this field. The furnace was developed especially for metallurgical process development on a pilot plant basis. High temperature resistant alloys, carbide tool steels, low alloy steels, and high nickel content alloys, are but a few of the current applications of this laboratory furnace. Prototype melts made prior to tonnage melts in production furnaces are also proving very effective and economical in the furnace. Easily adaptable to a variety of pouring techniques, this furnace is also being used on a production basis for small-size precision castings.

Basically, three systems have been incorporated into one compact package in the 50 lb furnace—the furnace chamber, the pumping system, and the high-frequency power supply. These parts are so inter-related that one operator can easily handle the main furnace as well as the auxiliary operations, with all general process operations and observations made from a single point. The furnace chamber is a tank 36in in diameter by 38in long, divided into halves by diagonal flanges. One section is mounted on free-rolling castors and contains the mould or moulds. The second half, which is stationary, is attached to the pumping system and high-frequency power supply, and holds an alloy addition device as well as the crucible and coil assembly. A guide is provided with the stationary chamber to ensure easy alignment of the removable chamber. The installation of the furnace has thus been simplified, and there is no necessity of digging up floors for tracks or pits. Three cover clamps are included to maintain a seal when back-filling the furnace with inert gas. The tank is a single shell with cooling provided by copper coils spot-brazed and back-filled with solder to obtain good thermal contact. The stainless steel construction of the shell keeps induction power losses to a minimum and provides for easy cleaning. A small shell volume facilitates rapid initial pump-down and rapid recovery from pressure surges.

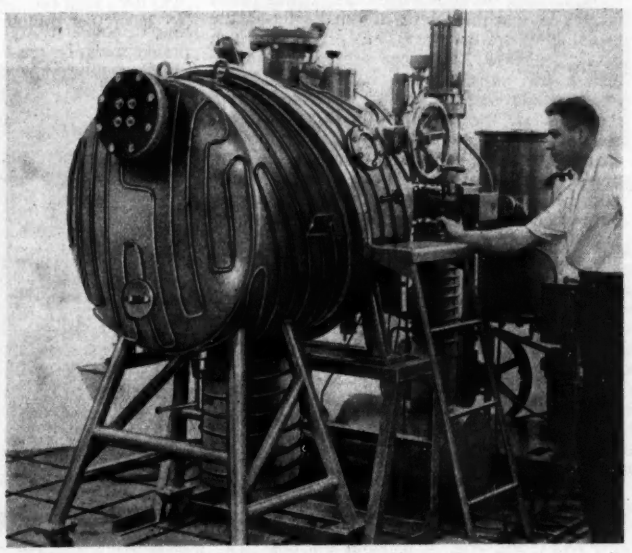


Fig. 1—50 lb " Consolidated Vacuum " vacuum induction melting and casting furnace

The stationary chamber is designed so that any interior part is within convenient arm's reach, and a step-ladder provides access to the chamber-top mechanisms. A 6in window, including a wiper and shield, is conveniently placed to allow observation of the crucible and the pouring operation. Also included in the stationary chamber is a manual bridge breaker combined with a water-cooled, non-fogging sight tube for optical pyrometry. Two spare ball-and-socket joints provide for the addition of accessory devices, such as an immersion thermocouple or sampling device. The crucible and coil assemblies are available in sizes to accommodate 5 lb, 12 lb, 17 lb, 30 lb or 50 lb melts, all of which are interchangeable in the one standard frame. The crucible is accessible to a fork truck or hoist, but is easily installed by two men without handling equipment. It is tilted for pouring by means of a hand-operated windlass. A radiation baffle, operated through a rotary vacuum seal, makes it possible to cover or uncover the crucible at any time during the operation of the furnace, and reduces the amount of radiation from the melt to the walls of the chamber. A pair of high-frequency flexible leads connected to fixed lead-throughs on the chamber wall supplies total power to the coil at any time, allowing for continuous adjustment of current during melting and pouring. These leads also carry the cooling water required by the coil at all times. The coil crucible assembly is furnished complete with leads, two linings, and electrical and water connections.

The 50 lb furnace can be supplied with or without the appropriate high-frequency power supply required for a particular application. The usual frequencies are 3000 c/s, 4200 c/s or 10,000 c/s, depending on crucible capacity. A frequency of 4200 c/s is recommended for general use. The alloy addition device is externally operated through a vacuum seal and permits alloy additions while under vacuum. It consists of a container with four addition cups, each of 25 cubic inches, and a removable cover to allow individual charging of each cup. A chute carries the alloy additions from the cups to the crucible and can handle most kinds of bulk material from large lumps to fine dust. Two connectors for vacuum gauge elements and two hand-operated globe valves for air and inert gas inlet are provided at the closed end of the tank.

A sampling device with a vacuum interlock can be used with one of the extra ball and socket joints to secure a sample for analysis without introducing atmosphere into the furnace chamber. The sampling device is often used to study the vaporisation rate of higher vapour pressure metals, and the change in alloy composition due to reactions between the crucible and the melt. Also available for mounting in a ball and socket joint is an immersion thermocouple, used primarily to obtain pre-pouring melt temperatures. A blanked-off 6in vacuum flange on the top of the furnace provides for the future addition of a bulk charging chamber with a vacuum interlock. This device permits the addition of a maximum of 50 lb of bulk material into the crucible without breaking vacuum in the main chamber. A motor-driven windlass with a rotary shaft seal is used for hoist control in the bulk charging chamber.

The removable furnace chamber is designed to meet almost any casting requirement. It permits starting with a comparatively simple, standard removable section for a single ingot, and later adding accessory provisions for multiple ingots and/or centrifugal casting. The design of the oblique angle flange dividing the furnace has resulted in unusual vertical clearance for removing moulds. A water-cooled mould, 17in deep with

a 13¼in internal diameter provides a 33in leeway under the crucible lip for long ingot moulds and for shape castings. Four electrical feed-through terminals are mounted in a vacuum flange for the resistance heating of the mould. Two compression connectors provide for the water cooling of the mould. The standard removable section includes a boss in the bottom of the chamber allowing for the quick and inexpensive addition of a multiple mould table as an accessory. The table is 18in in diameter and provides space for multiple moulds whose overall height, including hot top device, does not exceed 12in. The positioning of the moulds under the crucible lip is accomplished by indexing with a lever which extends below the tank.

The pumping system of the 50 lb furnace produces the low pressures required for a gas-free atmosphere, while providing ample capacity up to a pressure of 1·5mm Hg for handling the surges caused by alloy additions, deoxidation, and pouring. Pre-pouring pressures range from 1 to 10 microns Hg for a 50lb melt of steel, with correspondingly lower pressures for smaller melts. The unit is supplied complete with the necessary pumps, valves, gauges and piping. All vacuum line valves are pneumatically operated with a single rotary sequence switch to actuate each valve for loading, rough pumping and fine pumping operations. A gauge indicates the chamber and forepump pressures on two direct-reading scales from 1 to 750 microns Hg. A filter is provided between the gauge tube and the furnace to protect the sensing elements from contamination by metallurgical dust. The standard pumping system consists of a "CVC KS-600" diffusion ejector pump, a 130 cubic feet per minute mechanical pump for both roughing and backing, and a 3·5 cubic feet per minute mechanical holding pump. The "KS-600" pumping system has been used successfully in a wide variety of metallurgical applications where the normal operating pressures are in the 1 to 10 micron Hg range. The 130 cubic feet per minute mechanical pump is supplied with a gas ballast valve for easier control of water vapour. During the roughing cycle the 3·5 cubic feet per minute mechanical pump is used as the holding pump for the diffusion ejector pump. Approximately one minute is required to rough a clean, dry and empty system down to 750 microns Hg. An additional two minutes are necessary to further reduce the pressure to three microns Hg.

Gas Liquefaction

The North American Philips Company, of Mount Vernon, New York, displayed an interesting gas liquefier which is shown in Fig. 2. The "Norelco" gas liquefier is of simple design and small proportions and produces liquid air at the touch of a button in a matter of minutes. In operation, helium is compressed in a chamber surrounded by a water jacket. The gas at constant volume passes through a regenerator where it gives up more heat, then it goes to an expansion chamber, where its volume increases, thus lowering temperature. Without decreasing volume, the helium is now moved back through the regenerator to the compression chamber where the cycle begins again. In returning to the compression chamber, the gas absorbs heat that was previously stored in the regenerator. The new machine is only 37in long, 20in wide and 34in high, excluding the swinging spout and concrete mounting base. It produces approximately 5 quarts of liquid air per hour. Air or the gas to be liquefied do not pass through the internal mechanism of the machine. Instead they enter a chamber surrounding the cylinder at normal atmospheric pressure, condensing on the cold surface of the head until the quantity is large enough to run off. The system provides an oil-free, high-purity product. If desired, selected gases or vapours can be passed over the head and liquefied.

The machine consists of a single cylinder containing two pistons, properly phased and actuated from two throws on the same crankshaft. The rod for the upper piston, called the displacer, slides through the centre of the lower piston and the crankshaft is arranged so that a phase difference of less than 90 deg. is maintained. At one point of the cycle, the lower piston and the displacer come close together, compressing the gas between them. As the helium is compressed, the displacer moves downward to enlarge the chamber above it. At the proper moment, the compressed helium is forced out of the compression chamber through the regenerator and into the expansion chamber, where cooling takes place. Next, due to the phasing of the piston and displacer, the volume of the compression chamber is increased and the expansion chamber volume decreased. Thus, the helium is moved back to the compression chamber without being compressed. The action on the gas during complete cycles can be described as compress-transfer, expand-transfer. The success of the design depends on the ability to move

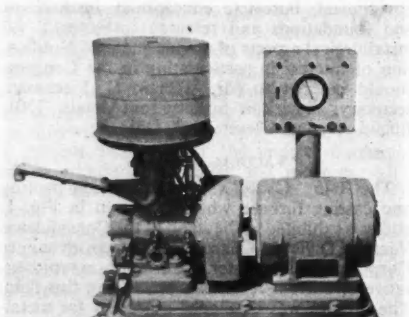


Fig. 2—"Norelco" gas liquefaction set for the production of liquid air

helium back to the compression chamber at essentially constant volume after the compression and expansion strokes.

The lower end of the cylinder is connected to a hermetically sealed crankcase from which the crankshaft emerges through a gastight bearing. The machine is driven by a 10 h.p. motor connected to the machine through a flywheel, clutch and ratchet. The ratchet prevents the machine from running backward if electric power is cut off. The machine stops automatically if the helium pressure exceeds 375 lb per square inch or drops below 220 lb per square inch. The helium gas under pressure is initially supplied to the crankcase through a check valve. From the crankcase, the gas passes through an exterior passageway to an oil extraction chamber, a buffer chamber, a check valve, and then into the compression section of the cylinder. During operation, helium is needed from the outside supply only when required to compensate for leakage. Since pressure is maintained in the crankcase, any leakage from the compression chamber to the crankcase is minimised. Before going into operation, helium is supplied to the system until the static internal pressure reaches approximately 225 lb per square inch. When the motor is in operation, the internal pressure reaches an average value of 310 lb per square inch. Water for cooling the machine is obtained from city water systems or from a conjunctive cooler. The machine stops automatically if the water pressure drops excessively.

The machine has a control panel on which is mounted the 0 lb to 600 lb per square inch pressure gauge. The panel also holds the flowmeter, a condenser pressure gauge, a low-pressure safety lock-out, a three-way valve for the flowmeter, and pilot lights for water pressure, manometer pressure and oil pressure. There is an hour counter to record the elapsed time the machine is in operation. Under ordinary conditions of humidity or in air-conditioned rooms, the machine can usually operate twenty-three hours out of twenty-four, allowing for defrosting. The gas liquefier is usually mounted on a concrete slab 37in long, 20in wide and 23in high, which rests on heavy rubber supports. The complete machine weighs 660 lb. It is expected that the new gas liquefier will be of great value to works and laboratories because air or selected gases can be liquefied conveniently in quantities as needed, avoiding the usual loss that results from transport and storage. The degree of cold produced by the machine ranges from −80 deg. to −200 deg. Cent.

Cutting Materials

There continues to be considerable interest in America in cemented oxide cutting tools and much attention was paid at this year's Metal Show to the combined cemented carbide and cemented oxide cutting arrangement which was demonstrated at the stand of the Metallurgical Products Department, General Electric Company, of Detroit, Michigan. By "teaming up" these two cutting tool materials on the same machining set-up, the firm believes it has the key to overcoming cutting problems at speeds ranging from 0ft to 2600ft per minute. Prior to the present development machining speeds below 100ft per minute on some steels using carbides were almost an impossibility. This was due to the seeming inability of carbides to withstand cuts on medium to soft steels at slow speeds, or the lack of machine tools with the speed versatility for the particular part being cut. At speeds above 1000ft per minute the picture was almost equally hopeless since carbides failed at the cutting edge despite their hardness at high red-hot heat.

The availability of superior grades of carbides and cemented oxides, together with proper tool design, now makes it possible to extend the machining horizon in two directions—above the current carbide cutting speed range and down into the "entrenched" high-speed steel cutting tool area. On the low-speed side, using carbides, the tool geometry plays an important part. Cutting forces increase rapidly below 200ft per minute on both positive 6 deg. and negative 5 deg. side rake tools, but these forces decrease as speed is reduced below 100ft per minute on the 5 deg. negative rake tools. In reaching for the high-speed side, ceramics seem to be the answer since the optimum speed of ceramic tools is much higher than that of carbides at speeds over 1000ft per minute. In Fig. 3 we show a 12in diameter blank of A.I.S.I. No. 6140 steel being faced in less than one minute by using a combination of carbide with cemented oxide. The cemented oxide tool here provides the mirror finish. A speed range of 0 to 600ft per minute was used with the carbide, and a range of 600ft to 2600ft per minute with the cemented oxide.

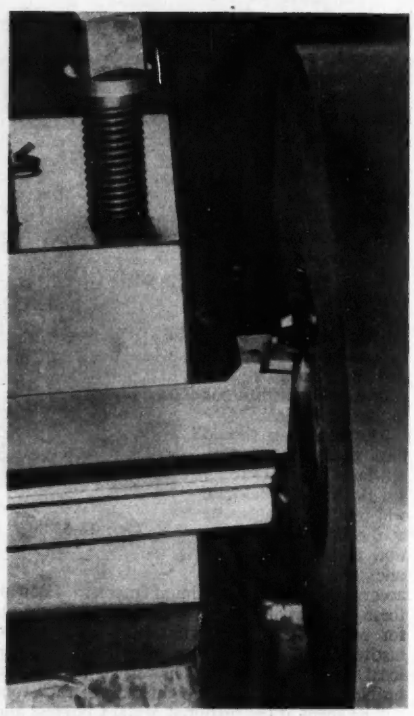


Fig. 3—Combination of cemented carbide [and cemented oxide tool set-up facing a 12in diameter steel blank

The depth of cut was $\frac{1}{16}$in and the feed was 0·0115in.

Another prominent American manufacturer of cemented carbides, Kennametal Incorporated, of Latrobe, Pennsylvania, displayed columbium and tantalum oxides and metals up to 99·5 per cent purity at this year's exhibition. Columbium, also known as niobium, when in a metallic state of high purity, is believed to offer highly desirable characteristics that are now needed in the atomic energy and chemical processing fields. As the availability of the metal in a high purity state has been limited, the announcement of production in volume by Kennametal was received with interest by metallurgists and engineers attending the Congress. In addition to the high purity grade, a technical grade of the oxide and metal will be made available for industrial research work as well as for commercial purposes. Tantalum metal and oxide of purity ranging up to 99·5 per cent is also now being made on a production basis by the firm. Widespread uses of this material have already been developed in several fields, especially in the making of electronic components.

Among the other products of the firm being displayed was a platinum base cemented carbide, developed to withstand extremely severe corrosive conditions. This material is claimed to be equal to the noble metals in resisting corrosion, yet is lower in cost and more wear-resistant. It is being applied in the form of seal rings, metering orifices, bushings, nozzles, and many other component parts used in the chemical processing industry. Finally, "Kenface," a cemented tungsten carbide hard facing material, was another new development that was exhibited. It is reported to be much stronger than the conventional fused and cast tungsten carbide hitherto used for wear-proofing surfaces. The material is being made available in a wide range of sizes and shapes which makes it adaptable as either a hard surfacing material or as a cutting agent when welded in the form of large granules on steel bodies. For rock cutting work the material is used in the form of core bits for penetrating rock formations.

Ultrasonic Jointing Equipment

A significant development at this year's exposition was the initial display of the "Sonoweld," "Sonobraze" and "Sonobond" metal jointing equipment by Aeroprojects Incorporated, of West Chester, Pennsylvania. Fundamentally, "Sonoweld" is an ultrasonic method for joining similar or dissimilar metals by the introduction of vibratory energy. In the process the pieces to be joined are clamped at low pressure between two welding members or "Sonotrodes," and the vibratory energy is briefly introduced. The result is a solid-state metallurgical bond, made in a short time, with low clamping load, low deformation and no fusion. The process utilises an ultrasonic transducer coupling system to produce and apply high-frequency vibratory energy to the weld zone. The transducer is the device which converts alternating current into mechanical vibration, which is then conducted by the coupling to the place where it is to accomplish welding.

The strength of "Sonoweld" joints in several materials is indicated in the following table. It is important to note that there need be no heat-affected or alloy zone when welding by this method.

Values of Ultrasonic Welds in Several Metals

Material	Thickness, in	Tensile shear load, average, lb
1100-H-14 aluminium ...	0·032–0·032 ...	290
	0·040–0·040 ...	340
	0·051–0·051 ...	390
2024-T3 bare aluminium...	0·020–0·020 ...	253
	0·032–0·032 ...	392
2024-T3 "Alclad" aluminium	0·032–0·032 ...	438
	0·040–0·040 ...	471
70-30 hard brass	0·010–0·010 ...	150
	0·016–0·016 ...	300
18-8 stainless steel, annealed	0·005–0·005 ...	100
	0·010–0·010 ...	225
	0·018–0·018 ...	390

The "Sonoweld" equipment can produce weldments under the following conditions: joining thin foil materials to heavy blocks, plates, rods, or other thin material; welding of dissimilar metals, such as aluminium to copper; sheet-to-sheet weldments of aluminium, cartridge brass and stainless steel; welding of small buttons of one metal to heavier sheet, plate, or a block of another metal.

Conventional brazing—the joining of two pieces of metal by melting another metal between them which will alloy with both—utilises a chemical flux. The operation is carried out at temperatures above 1000 deg. Fah. Many metals and new alloys, however, are highly resistant to brazing materials. While flux ordinarily overcomes that resistance the flux itself creates additional problems, particularly where corrosion is a critical factor. Now, "Sonobraze" is said to bring significant improvements to the brazing technique: in the simplification of the task, in the elimination of the need for flux, and in widening the field of those metals which can be successfully brazed. "Sonobraze" is ultrasonic equipment for fluxless brazing and for metal coating. Supplied in a line of models for heavy-duty industrial work, each machine basically consists of an ultrasonic generator, an ultrasonic brazing head which includes a transducer-coupling, a brazing tip, and either a gas-fired or electrically-heated tip. The equipment is designed to be used with brazing materials which

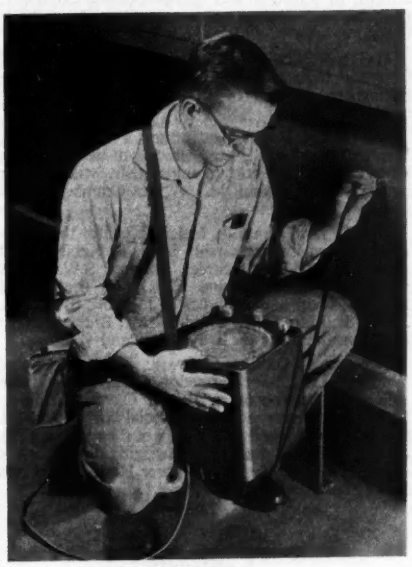


Fig. 4—"SO-200 Sonizon" portable ultrasonic thickness-measuring instrument

melt at less than 1300 deg. Fah. A wide range of standard or special brazing alloys can be used with the process, without special preparation. Sound joints can be obtained, it is stated, between aluminium sheet, sand and die castings, extrusions, tubing, wire and busbars. The high-frequency vibratory energy produced in the transducer of the machine head is transmitted by means of a metal coupling to the molten brazing material. This ultrasonic energy breaks down even heavily oxidised surface film on metals and permits the molten brazing material to alloy with the base metal.

The ultrasonic generators to drive the "Sonobraze" heads operate on 115V or 230V, 60 c/s a.c., and are supplied in 25W and 110W sizes. For special high-production industrial operations, generators are available in 300W, 600W and 2000W output. The brazing head receives high-frequency current from the generator and converts it to acoustical energy. This vibratory energy, in the range of 15,000 c/s to 60,000 c/s, is transmitted to the brazing tip. The transducer-coupling in the brazing head is either air-cooled or water-cooled.

Finally, "Sonobond" is the name given to the ultrasonic equipment for fluxless soldering and metal coating. Each unit consists basically of an ultrasonic generator, an ultrasonic soldering head which includes a transducer-coupling, a soldering tip, often a tip heater, and usually a heating platen. The high-frequency energy produces cavitation in the molten solder, tearing off protective films on the metal to be soldered and permitting the solder to alloy with the base metal. The parts to be soldered are heated to a temperature slightly above the melting point of the solder. The tip of the ultrasonic head is brought into contact with the molten solder as it is applied to the heated surfaces. The metal coupling in the soldering head transmits the rapid vibrations to the solder and, in one to ten seconds, the soldering job is complete.

Ultrasonic Thickness Meter

In addition to its well-known large scale ultrasonic equipment, the Magnaflux Corporation, of Chicago, Illinois, displayed an interesting new portable thickness-measuring instrument which is shown in Fig. 4. Known as the "SO-200 Sonizon" instrument, it is completely portable and is operated by dry cell batteries. It weighs only $9\frac{1}{2}$ lb and the battery with its case weighs only $6\frac{1}{2}$ lb. The battery life is forty hours at six hours per day. The instrument measures from 0·025in to 5·00in with only three crystals. It gives visual presentation with an accuracy of plus or minus 2 per cent. In operation, the inspector carries the unit over his shoulder. It is designed so that the dial and controls face upwards. The battery case hangs from belt clips. The operator screws a crystal into the handle of the 3ft probe lead and turns the selector switch to the appropriate range. At the same time he sets the harmonic dial on the same range. He uses a little oil or glycerine to obtain ultrasonic coupling and puts the crystal on the test area. A number of lines will appear on the screen. He turns the dial to watch these lines, and then takes the reading directly from the printed scale.

Ultrasonic Cleaning Equipment

A new range of ultrasonic cleaning equipment was displayed on the stand of the Branson Ultrasonic Corporation, of Stamford, Connecticut. These "Sonogen" cleaning units were designed specifically for the bench-top cleaning of small, delicate, intricate parts that must be "surgically" clean, such as watch movements, instrument components, small ball bearings, electronic parts and the like. The cleaning-tank capacities are one pint, one quart, and half a gallon, with the effective cleaning areas being 10, 12 and 18 square inches respectively. Ultrasonic cleaning involves the activation of the cleaning solvent by high-frequency energy, with the more rapid and thorough dislodging of soils than is possible with conventional cleaning methods. The number of cleaning stages is usually reduced, a lower solvent temperature is possible, and many soils normally considered insoluble can be removed. The cleaning energy originates as a high-frequency electrical current in the ultrasonic generator, and is converted to mechanical energy by a transducer of barium titanate—a ceramic material with the property of changing its shape synchronously with an alternating current applied to it. When the transducer is immersed in the solvent its vibrations of the order of 40 kc/s enter the fluid and pass with little loss through a metal in contact with it. Cavitation exerts a gentle yet thorough scrubbing action that literally blasts loose the soil and dirt. This action occurs on all surfaces, even deep in blind holes when penetrated by the solvent, yet will not damage delicate parts.

The "Sonogen" ultrasonic generator is a self-contained source of high-frequency electrical power, tunable between 36 kc/s and 40 kc/s, with an output averaging 50W and reaching 200W on pulse peaks. The cleaning units are cylindrical tanks of stainless steel with the barium-titanate transducers sealed hermetically into the base in such a way that the ultrasonic energy is transmitted efficiently into the cleaning solvent. When conditions require more than one cleaning stage, such as a rinse to remove residual soil-carrying solvent from the first stage, or when two different solvents are to be used, two tanks may be driven alternately, provided the effective cleaning area in use at any one time does not exceed 24 square inches.

(*To be continued*)

Personal and Business

Appointments

MR. J. E. GRAY has been appointed chairman of the Junior Institution of Engineers.

SIR GEORGE BRIGGS has been appointed deputy chairman of Thompson Brothers (Bilston), Ltd.

DR. ALEXANDER KING has been appointed deputy director of the European Productivity Association.

F. PERKINS, Ltd., Peterborough, has announced the appointment of Mr. John Spiers as senior experimental engineer.

SHEEPBRIDGE ENGINEERING, Ltd., states that Mr. C. Hand has been appointed to the board of Sheepbridge Equipment, Ltd.

MR. ALLEN JONES has been appointed sales manager of Glass Yarns and Deeside Fabrics, Ltd., Kingsway, London, W.C.2.

MR. A. F. PLUMMER has been appointed deputy chairman of the National Inspection Board for Electrical Installation Contracting.

MR. H. F. AKEHURST, A.M.I.E.E., has been appointed to the board of British Insulated Callender's Cables, Ltd., as director (overseas operations).

R. B. PULLIN AND CO., Ltd., Great West Road, Brentford, states that Mr. G. B. Jeffery has been appointed technical sales manager of the Kearfott division.

MR. P. M. TAPSCOTT has been appointed a financial director of Laurence, Scott and Electromotors, Ltd., Norwich, in succession to Mr. H. S. Loebl, who is retiring from the board.

THE BRITISH TRANSPORT COMMISSION has announced the following appointments to its general staff at headquarters :—Mr. F. T. Gray, assistant director of costings ; and Mr. D. V. Ellison, works officer.

MR. F. H. WOOD has been appointed manager of Brush Traction, Ltd. He succeeds Mr. H. G. Ivatt, who has retired from executive responsibility, but who continues to serve on the company's board.

MR. P. T. HOULDCROFT has been appointed chief metallurgist of the British Welding Research Association. He succeeds Mr. H. E. Dixon, who has taken up an appointment with Richardsons Westgarth Atomic, Ltd.

MR. L. W. STEVENS-WILSON has been appointed development officer of the British Iron and Steel Research Association, in succession to Dr. T. E. Dancy, who has resigned in order to take up an appointment in the U.S.A.

THE MINISTRY OF SUPPLY states that Brigadier G. Kellett has been appointed director-general of artillery, in succession to Major-General H. M. Paterson. Colonel W. P. T. Roberts is to succeed Brigadier Kellett as director of inspection of armaments.

G. AND J. WEIR, Ltd., Glasgow, has announced the appointment of Mr. Luke Fraser as London manager. He succeeds Mr. A. C. Smith, who has returned to Glasgow as sales director. Mr. F. T. Randell succeeds Mr. Fraser as the firm's Scottish sales representative.

MR. RONALD DINGWALL, M.I.E.E., has been appointed deputy chief engineer of Dorman Long (Steel), Ltd. He has been works manager at the company's Lackenby steel works since 1953. Mr. J. S. Curphy has been appointed superintendent of all the Dorman Long (Steel), Ltd., steel plants.

THE BRITISH TRANSPORT COMMISSION has appointed a panel of consulting engineers for advice on technical problems associated with British Railways' electrification scheme. The members of this panel are Mr. J. S. Tritton, M.I.C.E., M.I.Mech.E., Mr. E. L. E. Wheatcroft, M.I.Mech.E., M.I.E.E., and Mr. Geoffrey Kennedy, M.I.Mech.E., M.I.E.E.

THE MINISTRY OF TRANSPORT AND CIVIL AVIATION states that Mr. J. S. McNeil, M.I.C.E., has been appointed deputy chief engineer (civil) of the highways engineering staff, in succession to Mr. G. H. Hargreaves, who is retiring at the end of January. Mr. J. G. Smith, M.I.C.E., has been appointed an assistant chief engineer (civil).

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, has announced the appointment of Mr. W. O. P. Jones, A.M.I.E.E., as assistant superintendent, electronics department. In the mechanical department, Mr. G. H. Butterworth, A.M.I.Mech.E., has been appointed superintendent, Mr. A. Cormack, assistant superintendent, and Mr. A. E. Clayton, works manager (Germiston Works), Metropolitan-Vickers Electrical Company, Ltd., has also announced the appointment of Mr. H. H. Lusty, A.M.I.E.E., as manager of the publicity department. He succeeds Mr. E. E. Walker, who is retiring.

Business Announcements

BRITISH OXYGEN GASES, Ltd., has opened a new factory at Brinsworth, near Rotherham.

ACME CONVEYORS, Ltd., 1, Bradford Street, Walsall, states that it has closed its London office.

TUBE INVESTMENTS, Ltd., has acquired the whole of the share capital of Bennett Tools, Ltd., Redditch.

LANCASHIRE DYNAMO HOLDINGS, Ltd., has acquired the business of J. G. Statter and Co., Ltd., Amersham Common, Bucks.

BROOK MOTORS, Ltd., Huddersfield, states that its Aberdeen sales office has been moved to 1, Bon Accord Crescent, Aberdeen.

HEDIN, Ltd., South Woodford, London, E.18, states that its sole agents in Scotland are James R. Turner and Co., 593, Nitshill Road, Glasgow, S.W.3.

THE DU PONT COMPANY (UNITED KINDGOM), Ltd., has taken a site near Londonderry, Northern Ireland, for the erection of a "neoprene" synthetic rubber plant.

MR. HENRY GARDNER, managing director of Glenfield and Kennedy, Ltd., Kilmarnock, has returned from a business trip to Australia and the U.S.A.

MR. C. G. H. RICHARDSON, M.I.Mech.E., managing director of Ransome and Marles Bearing Company, Ltd., Newark-on-Trent, is touring Canada and the U.S.A.

MARSTON EXCELSIOR, Ltd., a subsidiary of Imperial Chemical Industries, Ltd., has taken over from the Billingham division of I.C.I. the manufacture of bursting discs.

THE BRUSH GROUP has formed a new company, Brush Export (India), Ltd., which will take responsibility for electrical sales in India. Mr. Miles Beevor is the chairman and Mr. A. L. Cramb, general manager.

MR. C. D. C. BRAINE, M.I.C.E., states that he is retiring from his partnership in G. B. Kershaw and Kaufman, 1, Victoria Street, London, S.W.1. His new firm of consultants, C. D. C. Braine and Partners, is opening an office at Jotham's Buildings, 26–27, St. Mary Street, Cardiff. Mr. Braine will act as a consultant for G. B. Kershaw and Kaufman.

THE BRITISH OXYGEN COMPANY, Ltd., and George Wimpey, Ltd., have formed a jointly-owned subsidiary to be known as British Oxygen Wimpey, Ltd., for the construction of special rocket projects. Sir Godfrey Mitchell is chairman of the new company and Dr. L. G. Groves is the managing director. The company's office is at Bridgewater House, Cleveland Row, St. James's, London, S.W.1.

Contracts

THE GLOUCESTER RAILWAY CARRIAGE AND WAGON COMPANY, Ltd., has received a contract for the supply of seventy-eight passenger coaches for the Rhodesia Railways. This follows a recent order from Rhodesia for ten coaches, the total value of the contract being over £1,500,000.

BRISTOL AIRCRAFT, Ltd., is to supply two "Britannia" 310 long-range airliners to the Hunting Clan Air Transport. They are valued at £2,500,000 and will be delivered in 1958. Of the sixty-two "Britannias" on order, twelve have already accumulated 7000 flying hours, and the prototype of the larger "300" series has been flying since July last.

THE STANTON IRONWORKS COMPANY, Ltd., has received an order from the Mid Northamptonshire Water Board for 9200 yards of 36in internal diameter prestressed concrete pressure pipes and "specials" with lock joints for a raw water main from Duston Mill to Pitsford, to connect the new Pitsford dam with main service reservoirs. The total value of the contract is £117,000, and it is expected that delivery will be required to start in March, 1957, and be completed in February, 1958.

WOODALL-DUCKHAM CONSTRUCTION COMPANY, Ltd., 63–77, Brompton Road, London, S.W.3, states that the South African Iron and Steel Industrial Corporation, Ltd., has ordered another coke oven installation, valued at approximately £2,000,000, for the Vanderbijl Park Works. This is the ninth battery of W-D Becker coke ovens to be ordered by "Iscor" and the fourth within the last two years. It comprises fifty-five ovens, as does the battery now nearing completion at Vanderbijl. Two further batteries of fifty-one ovens are also under construction at the Pretoria Works. The total value of these four contracts approaches £6,000,000.

Miscellanea

RAYON CORD TYRES.—Courtaulds, Ltd., has prepared a black and white sound film, 16mm or 35mm, called "Travellers' Yarn," to publicise the use of "Tenasco" in rayon cord tyres. Processes in the manufacture of rayon and of tyres are shown, while there are shots of vehicles in action at the M.I.R.A. and on the road. There has also been printed a booklet explaining this use of rayon ; admirers of draughtsmanship will enjoy the multifarious drawings by Brockbank that comprise the cover design.

OILER FOR MINE GAUGE GUIDE ROPES.—A note from the National Coal Board describes a device to simplify the lubrication of cage guide ropes, which has been used successfully at Oakdale Colliery, Monmouthshire. The device was developed by the colliery's rope smith, Mr. S. Laffan, and it consists of a metal tube forming an oil bath through which the guide rope passes. An oil seal is provided by spring-loaded rubber sealing rings, which allow the oiler to adapt itself for moderate wear of the guide rope. When oiling is to be carried out the device is fitted around the guide above the cage horn and shackle, and a chain is fastened between the oiler and the cage chain to ensure that it descends with the cage. The device is filled with oil, and as the cage slowly descends for the whole of the winding depth an operator tops it up with lubricant when necessary. As the guide rope passes through the oiler it is first cleaned of water and old grease by the scraping action of the device ; it is then covered with lubricant, any excess of which is wiped off by spring-loaded wipers at the top end of the oiler. Surplus oil is returned to the oil bath for further use.

NATIONAL COAL BOARD UNIVERSITY SCHOLARSHIPS.—This year the National Coal Board has awarded scholarships in mining engineering and allied subjects to forty-one young men employed in the mining industry and to forty boys outside it. During the year fifty-nine men on National Coal Board scholarships have graduated from universities and passed on for further training in the industry. The scholarships cover the whole cost of education and carry a maintenance allowance, which may amount to £348 a year, irrespective of family income. Extra allowances for married men and men with dependants are payable. Since the scheme started eight years ago, 669 scholarships have been awarded ; 312 students have graduated and most of them have now entered the industry's directed practical training scheme, which follows graduation and lasts three years. Up to 100 scholarships are offered each year. They are open to boys from school who have reached a good standard in the advanced level of the General Certificate of Education or the Scottish Leaving Certificate. Young men employed in the industry with university entrance qualifications, and university graduates who wish to extend their qualifications are also eligible.

INSTITUTION OF NAVAL ARCHITECTS.—On December 6, at a meeting of the Institution of Naval Architects, M. A. Augustin-Normand, Jun., and M. Barthalon read a paper entitled "Some Problems in Design and Use of Free-Piston Gas Generators on Board Ships." After remarking that free-piston gas generators approached the simplicity of the reciprocating steam engine, the paper recalls that GS34 gas generators were delivered to Electricité de France in 1951, and the first merchant vessels to be equipped were the "Cantenac" and "Merignac," both in 1954. Installation problems are considered and tabular statements together with graphs set forth the space requirements and the weight per horsepower of different forms of propulsion equipment. The paper next considers the question of performance and quotes fuel consumptions recorded at a power station and on board minesweepers and a Liberty ship at full load. A graph illustrates the relationship between consumption and gas delivery pressure and a second graph considers the results of applying the principle of recirculation of hot compressed air to the compressor intake. In the section on control and astern operation the employment of a gas turbine with ahead and astern stages is discussed, together with the resulting points of development. Also considered are the stability of operation of the gas generator and the design of the turbines, including a graph showing the efficiency of a turbine over a range of loading. Teething troubles encountered during the first three years of operation, such as wear, oil consumption and engine fouling, &c., are remarked upon, followed by comments related to operational problems, including noise level in the engine-room, and duties of personnel. Tables are given of information concerning intervals between inspections of various parts, observed wear, and the replacement intervals of engine components.

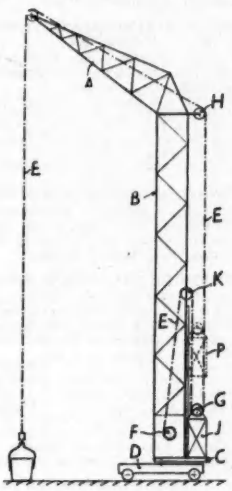
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

CRANES AND LIFTING APPLIANCES

760,151. April 6, 1954.—SAFETY DEVICE FOR LIFTING APPLIANCES, Andre Faure and Antoine Faure, Rue Dorian, Firminy (Loire), France.

The invention has for its object a safety device for lifting appliances having a lifting cable and winding drum, and particularly, but not exclusively, for cranes. As will be seen from the drawing, *A* is the jib, *B* the crane tower, *C* the platform of the tower, and *D* the base carriage on which the platform is pivoted. *E* is the lifting cable, *F* the winding drum. According to the form shown, the cable *E*



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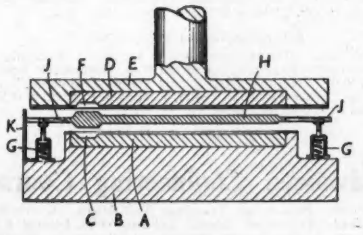
instead of passing directly from the pulley *H* to the drum *F*, is first taken downwards and over a pulley *G* journalled on a counterweight *J* resting on the platform *C*, and then upwards and over a pulley *K* on the tower. By allowing the counterweight to rest on the platform, it not only serves as part of the safety device, but also to assist in balancing the crane. By virtue of the path of the cable *E* it exerts a direct lifting action on the counterweight. The weight of the counterweight is slightly in excess of that enabling the maximum permissible load to be lifted without its rising from the support, and it will be lifted if an excessive load is attached to the hook. The counterweight is guided along the tower of the crane and it rises to the position shown by the dotted lines with an excessive load on the hook. This displacement of the counterweight is used to stop the drum by operating a lever which declutches the driving drum or it may be arranged to actuate a switch which breaks the power supply. The same safety device applied to a swivelling tower crane is also shown in the specification.—*October* 31, 1956.

METALLURGY

760,132. December 22, 1953.—FORGING METHODS AND APPARATUS, Rolls-Royce, Ltd., Nightingale Road, Derby, and Daniel Doncaster and Sons, Ltd., Penistone Road, Sheffield. (*Inventors: Frank Nixon and Richard Tobey Doncaster.*)

The invention relates to forging methods and apparatus, particularly for forging thin sections in materials such as ferrous metals, aluminium, titanium and aluminium, titanium and nickel-chromium alloys. The drawing shows apparatus for the forging of thin-section compressor blades. A lower die-block *A* is supported in a base *B* and it has a recessed forming



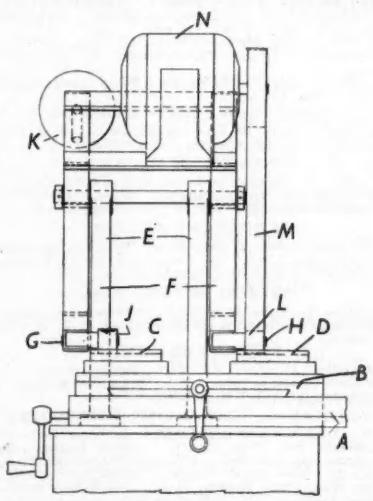
No. 760,132

surface *C* to the required profile and root shape of the blade. The upper die-block *D* is in a moving support *E* and recessed to the shape of the blade. Resiliently-loaded blank support means are shown at *G* and comprise yoke elements supported on "piston" rods suitably guided to ensure accurate movement and loaded resiliently by coil-springs. The blade blank is shown at *H*, having welded to its extremities rod elements *J*. The rods may be of an inferior material as compared with the material of the blade blank. Alternatively the rods may be formed integrally with the blade blank. After heating the blank to forging temperature it is inserted between the forging dies so that the rods *J* rest in the yokes. An end stop plate *K* is provided. To obtain accurate axial location the rod element adjacent the stop-plate will be machined to desired length. In this manner, as illustrated, the blank is suspended out of contact with the surfaces of the dies *A* and *D*. Application of forging pressure initially causes the blank to be received in the die recess, thereafter the resilient supports are depressed, resulting in the forging of the blank between the two die surfaces. It will be noted that the moving support structure *E* extends beyond the ends of the blade blank, whereby the extensions engage the rods *J*. In this manner bending or distortion of the rods is avoided, permitting, if necessary, successive forging operations in quick succession.—*October* 31, 1956.

MACHINE TOOLS

760,594. November 11, 1953.—A MACHINE FOR GRINDING AND POLISHING TURBINE AND GAS COMPRESSOR BLADES, Roland Goodall, 112, Green Lane, Derby.

The invention has for its object to provide in a simple form a machine for grinding and polishing blades for turbines and gas compressors. As is clearly shown in the drawing, the base has two slides *A* and *B*, the top slide *B* being thus movable in any direction, and it carries the pattern *C* and the workpiece *D*. Adjustably mounted on the base are a pair of brackets E, to the upper ends of which is pivotally attached a double arm *F*. The lower and free ends of the arm carry coaxial spindles *G* and *H*. On the spindle *G* is a pulley *J*, which is held in contact with the pattern *C*



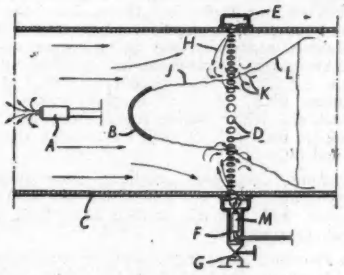
No. 760,594

by the weight of the arm which has a suitable counterweight *K*. The other spindle *H* carries a pulley *L*, around which passes an abrasive endless band *M* for acting on the workpiece *D*. The band is driven by the motor *N* on the double arm. The arrangement is such that by movement of the two slides *A* and *B* on the base the abrasive band reproduces on the workpiece the profile of the pattern *C*. This movement may be effected by operating the slide handles shown or by an appropriate power-driven mechanism.—*November* 7, 1956.

GAS TURBINES

761,167. May 6, 1954.—FLAME SPREADING DEVICE FOR COMBUSTION SYSTEMS, Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, 150, Boulevard Haussmann, Paris. (*Inventors: Benjamin Salmon and Jean Henri Bertin.*)

The invention provides a device for promoting the spreading or transverse propagation of a stabilised flame within a high-velocity gaseous stream flowing through a combustion chamber and stabilised by a flame stabiliser upstream of the device. In the drawing there is shown a combustion chamber, through which the combustion supporting gas passes from left to right. An injector device *A* is arranged on the upstream side of a flame stabiliser *B* and injects fuel preferably in a direction opposite to that of the gas flow. Without limitation of the invention, there is shown a flame stabiliser comprising a solid screen *B*, which creates downstream a wake zone of reduced speed in which the flame can maintain itself. It will be clear that the flame stabiliser may be constituted by a fluid screen such as described. In a suitably located plane the wall of the chamber *C* is pierced to form one or a number of rows of orifices *D*, the axes of which may or may not be inclined at an angle to the direction of flow. These orifices are spaced from each other a distance substantially equal to or greater than their size, measured transversely. By means of a collector chamber *E* and a pipe *F* provided with a valve *G* the orifices may be connected to a source of compressed air or other gas, the total pressure of which is greater than the static pressure obtaining in the gas stream in the zone of the orifices. The shape of the orifices *D* is preferably adapted to produce elementary jets which penetrate to a considerable extent into the main gas stream. These jets *H* give



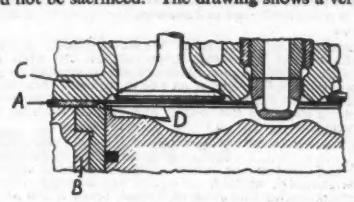
No. 761,167

rise at their origin to very small wakes in the main gas stream and there is thus no risk of stabilising a ring of flame in the peripheral zone of the chamber *C* where it would not be desirable, as it would be liable to cause deterioration of the wall of the chamber. The position of the jets with respect to the stabilising screen *B* is such that the zone of microturbulence which they produce by diffusion in the main gas stream is located downstream of the stabiliser. Starting from the stabiliser *B*, a front of flame *J* is initiated with a relatively low transverse speed. Starting from the zone of turbulence created by the jets *H* and shown diagrammatically by the vortices *K*, the activity of combustion is accelerated and this is accompanied by an increase in the transverse speed of propagation and an increased inclination of the resulting front of flame *L*. A fuel injector *M* inside the pipe *F* supplies air to the collector chamber *E*. This injector receives a portion of the fuel which is to be burned inside the chamber (the greater part of the fuel being introduced through the injector *A*) and sprays it into the air which supplies the chamber *E*. In this way advantage may be taken of the division of the air jets produced by the orifices and of the turbulence created by these jets within the chamber *B* to obtain a fine spraying effect of the fuel introduced in this way into the chamber, even if the spraying effect of the injector *M* in the collector *E* is only coarse. The specification also describes several other modified forms of flame spreaders.—*November* 14, 1956.

INTERNAL COMBUSTION ENGINES

761,020. October 20, 1954.—CYLINDER HEAD SEALS, Daimler-Benz Aktiengesellschaft, Stuttgart-Unterturkheim, Germany.

An object of the invention is to provide cylinder head sealing means, in which ordinary flat packings subject to the full pressure of the head can be used and for which simple machining and easy assembly need not be sacrificed. The drawing shows a vertical



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section of the parts of a diesel engine cylinder with a pre-combustion chamber head. It will be seen that a disc or platelike gasket *A* is inserted between the cylinder block *B* and the cylinder head *C*. The gasket is screened against the cylinder space by a lip or rim-like projection *D* provided on the liner and extending towards the flat joint surface of the cylinder head. The distance between the top of the liner rim and the flat surface of the cylinder head may be only about 0·2mm, which affords a clearance for production purposes or the clearance necessary for permitting thermal expansion of the parts.—*November* 7, 1956.

Launches and Trial Trips

CRUX, closed shelter deck cargo ship; built by Alexander Stephen and Sons, Ltd., for Det Bergenske Dampskibsselskab, Norway; length 400ft, breadth 57ft, depth 25ft, draught loaded 23ft, deadweight 6530 tons, 14½ knots; twelve passengers, five cargo holds, one 50-ton, one 30-ton and a complement of 3-ton, 5-ton and 10-ton derricks, electric winches; three 180kW diesel-driven generators; Stephen-Doxford, two-cycle, diaphragm oil engine, with Doxford-Bibby detuner, four cylinders, 670mm diameter by 2320mm combined stroke. Trial October.

ARGYLLSHIRE, cargo passenger liner; built by The Greenock Dockyard Company, Ltd., for the Scottish Shire Line, Ltd.; overall length 535ft, length between perpendiculars 497ft, breadth moulded 69ft, depth moulded 41ft 7in, deadweight 11,250 tons on 28ft 3in draught; speed 16¾ knots; twelve passengers; six holds totalling 600,000 cubic feet of cargo space, including 378,000 cubic feet for refrigerated cargo; one 105-ton, two 40-ton, four 15-ton, four 7-ton and twelve 5-ton derricks, electric winches; four 300kW diesel-driven generators, one set of Parsons double reduction geared, triple-expansion turbines, 10,500 service s.h.p. at 112 propeller r.p.m., 11,550 maximum s.h.p. at 115·5 propeller r.p.m., two Babcock and Wilcox boilers supply steam at 415 lb per square inch and 750 deg. Fah. Trial, October 17th and 18th.

AYRSHIRE, cargo-passenger liner, sister ship to "Argyllshire," built by The Greenock Dockyard Company, Ltd., for the Scottish Shire Line, Ltd. Launch, October 19th.

LA PRADERA, cargo ship; built by the Chantiers de L'Atlantique Penhoet-Loire, for Buries Markes, Ltd.; length between perpendiculars 452ft, breadth moulded 61ft, depth moulded 40ft 6in, deadweight 10,824 tons; speed 14 knots; five holds; one Burmeister and Wain two-stroke, pressure-charged diesel engine, 4600 h.p. Trial, October.

ALEXANDER BRUCE, trawler; built by John Lewis and Sons, Ltd., for the Minerva Fishing Company, Ltd.; length overall 133ft, breadth 25ft 6in, depth moulded 12ft 9in, gross tonnage 300; fish room 6500 cubic feet, 150 b.h.p. trawl winch with barrel capacity 800 fathoms of 2¾in warp; two 20kW diesel-driven generators, one 125kW diesel-driven generator; Widdop-GMB7 diesel engine, 640 b.h.p. at 250 r.p.m. Launch, November 5.

Catalogues and Brochures

FISHER DEANE ENGINEERING COMPANY, Ltd., 39, Victoria Street, London, S.W.1 (sole agents of Ernst Grob, of Munich).—Illustrated leaflet giving details of the new high-duty continuous band filing machines. The difference between the new types and old types is illustrated.

SLIP PRODUCTS AND ENGINEERING COMPANY, Ltd., 34, Great St. Helens, London, E.C.3.—Publication entitled "The Furnaceman's Guide to Fuel Oil Additives," explaining why additives are sometimes necessary, and what results should be expected from the use of certain types.

DOWSON AND MASON, Ltd., Alma Works, Levenshulme, Manchester, 19.—Bulletin No. IB, dealing with car bottom furnaces, illustrating and giving specifications of gas, coal and oil-fired furnaces with particulars of operating temperatures and maximum fuel capacities.

CAMBRIDGE INSTRUMENT COMPANY, Ltd., 13, Grosvenor Place London, S.W.1.—Brochure commemorating the seventy-fifth anniversary of the foundation of the company, giving details of its uninterrupted progress. Reference is given to instruments made and developed by the company.

THE CROWTHORN ENGINEERING COMPANY, Ltd., Atlas Works, Reddish, Stockport.—Leaflets illustrating the 12in/12½in centre lathes and the 12¼in combination turret lathe; 15in/18in centre lathes; 30in/36in range of swing boring and facing lathes; and the 8½in parting-off, turning and boring lathe.

PLESSEY COMPANY, Ltd., Chemical and Metallurgical Division, Wood Burcote Way, Towcester, Northants.—Illustrated brochure giving technical details and performance data of a new range of components and materials for application in the fields of television, radio and electronic equipment. Copies of this brochure which is entitled "Plessey at Towcester," are available to design engineers.

HADFIELDS, Ltd., East Hecla Works, Sheffield.—Brochure No. 523, entitled "Hadfield's Improved Tub and Mine Car Controllers." The machines illustrated can be supplied to pass one, two, three or four tubs or on axle as required. Also leaflet No. 521, entitled "Hadmang" and "Heckweld" dealing with arc welding electrodes and welding rods for hard surfacing and reclamation.

THE ENGLISH ELECTRIC COMPANY, Ltd., Queens House, Kingsway, London, W.C.2.—Illustrated brochure giving details of electric and diesel-electric traction equipment designed and built by this company, which is in regular use in many different countries, including New Zealand, France, Brazil, South Africa, India, Japan, &c. Principal dimensions and technical data are given for all units described.

S. BROD AND CO., Ltd., 31–33, Priory Park Road, London, N.W.6.—Leaflet illustrating and giving full details of an inexpensive electronic motor control. The speed of the motor can be controlled, to maintain constant tension, pressure, temperature, thickness, light intensity irradiation, &c., and control is obtained by an xenon filled thyratron, which is claimed to have none of the disadvantages associated with the older type of mercury vapour thyratron.

AMBER OILS, Ltd., 11A, ALBEMARLE STREET, LONDON, W.1.—An illustrated operation manual containing information and practical guidance for engineering and machine shop executives. The book deals with the use of cutting, drawing and heat-treatment oils. Details are given of the properties of the various brands of "Amber" cutting oils, together with instruction on their use. A chart is included listing the types of oil most suited to certain operations with the different metals encountered. This chart is available separately.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Tues., Dec. 18.—LONDON NATIONAL LECTURE: E.L.M.A. Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, "In Search of Coal," W. H. Brooks, 6.30 p.m.
Wed., Dec. 19.—NOTTINGHAM BRANCH: E. Midlands Electricity Board's Showroom Theatre, Smithy Row, Nottingham, American Industrial Films Evening, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

To-day, Dec. 14.—S. MIDLANDS SECTION: Technical College, Cheltenham, "Radio Astronomy," R. L. Adgie, 7 p.m.

COVENTRY ENGINEERING SOCIETY

Tues., Dec. 18.—Room A5, Technical College, Coventry, "Television," D. Bauer, 7.30 p.m.

DIESEL ENGINEERS AND USERS ASSOCIATION

Thurs., Dec. 20.—GENERAL MEETING: Caxton Hall, Westminster, London, S.W.1, Report on Heavy Oil Engine Working Costs and Performance, 1955, 2.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., Dec. 18.—LIVERPOOL CENTRE: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, "Interesting Lighting Installations," 6 p.m.
Wed., Dec. 19.—N. LANCASHIRE GROUP: N.W. Electricity Board, 19, Friargate, Preston, School Lighting, Part 2, (*a*) "Electrical Contracting," F. Ainscow; (*b*) "Decoration," J. M. McEwing, 7.15 p.m.——TEES-SIDE GROUP: Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "How to Live with Light," R. J. Fothergill, 6.30 p.m.
Thurs., Dec. 20.—MANCHESTER CENTRE: N.W. Electricity Board, Town Hall, Manchester, "Colour Matching," A. Wilcock, 6 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Dec. 14.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, Mobile Plant Discussion Group, "British Tractors," 7.30 p.m.
Tues., Dec. 18.—GLASGOW BRANCH: Scottish Building Centre, 425/427, Sauchiehall Street, Glasgow, C.2, "Heating and Ventilation of Factories," D. T. Jenkins, 7 p.m.
Wed., Dec. 19.—KENT BRANCH: Kings Head Hotel, High Street, Rochester, "Plant Planning and Development," A. W. Western, 7 p.m.
Thurs., Dec. 20.—BLACKBURN BRANCH: Golden Lion Hotel, Blackburn, "Feedwater Treatment," D. Warburton, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

To-day, Dec. 14.—TEES-SIDE BRANCH: Teesdale Hall, Head Wrightson and Co., Ltd., Thornaby-on-Tees, "Some Notes on Foundries," Charles Wilson, 7.30 p.m.
Sat., Dec. 15.—E. MIDLANDS BRANCH: Gas Showrooms, Nottingham, "Foundry Developments," D. Killingworth, 6 p.m.
Tues., Dec. 18.—E. ANGLIAN SECTION: Public Library, Ipswich, Film Evening, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., Dec. 17.—W. OF ENGLAND SECTION: Grand Hotel, Bristol, "S.S. British Sovereign," films, 7.30 p.m.

INSTITUTE OF METALS

Mon., Dec. 17.—BIRMINGHAM LOCAL SECTION: Physics Department, The University, Edgbaston, Birmingham, Christmas Lecture for Schoolchildren, E. A. G. Liddiard, 2.30 p.m.

INSTITUTE OF NAVIGATION

To-day, Dec. 14.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Port Operation in Fog," L. S. le Page, W. R. Colbeck and R. F. Hansford, 5.15 p.m.

INSTITUTE OF PETROLEUM

Wed., Dec. 19.—STANLOW BRANCH: Grosvenor Hotel, Chester "Pollution Abatement in the Oil Industry," A. W. W. Kirby, 7.30 p.m.

INSTITUTE OF PHYSICS

To-day, Dec. 14.—NON-DESTRUCTIVE TESTING GROUP: 47, Belgrave Square, London, S.W.1, "Some Conductivity Test Methods and Results," R. W. Powell, 6.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

To-day, Dec. 14.—S. WALES GROUP: S. Wales Institute of Engineers, Park Place, Cardiff, "Current Trends in Fuel Injection Equipment for Road Transport," J. Skinner, 7 p.m.
Thurs., Dec. 20.—LONDON CENTRE: Royal Society of Arts, John Adam Street, London, W.C.2, "The Use of Plastics in Road Transport," M. D. Curwen, 6.30 p.m.——YORKSHIRE CENTRE: Great Northern Hotel, Wellington Street, Leeds, "Exhaust Brake Design and Operation," A. G. Slee and W. K. Cox, 7.30 p.m.

INSTITUTE OF TRANSPORT

Mon., Dec. 17.—80, Portland Place, London, W.1, Annual General Meeting, Corporate Members, 5.45 p.m.——SHEFFIELD GRADUATE AND STUDENT SOCIETY: Visit to British Railways Parcels Depot, Tuffnell, 7 p.m.
Tues., Dec. 18.—HUMBERSIDE SECTION: Chamber of Commerce and Shipping, Hull, "The Commercial Prospects of British Commerce and Shipping," H. F. Sanderson, 7.30 p.m.——YORK GRADUATE AND STUDENT SOCIETY: Railway Headquarters, York, "Modern Developments in Railway Signalling," G. G. F. Halliwell, 7 p.m.
Thurs., Dec. 20.—BOURNEMOUTH-POOLE GROUP: Town Hall, Bournemouth, "Road Planning Aligned with Traffic Conditions," E. C. Whitaker, 6 p.m.——MANCHESTER GRADUATE AND STUDENT SOCIETY: Corporation Transport Offices, Manchester, "Publicity in a Road Passenger Traffic Department," F. Holland; "A Transport Plan for the Greater Manchester Area," K. R. Sutton, 6.15 p.m.
Fri., Dec. 21.—TEES-SIDE SECTION: Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Productivity in Transport: Industrial Transport," D. J. Wilkinson; "Road Transport,"; D. S. Deacon; "Docks," E. Halder; "Railways," S. H. Giles, 7 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Wed., Dec. 19.—SCOTTISH CENTRE: North of Scotland College of Agriculture, Aberdeen, "Application of Hydraulics to Agricultural Machinery," J. C. McNeice, 7.30 p.m.
Thurs., Dec. 20.—SCOTTISH CENTRE: Newhouse Hotel, Lanarkshire, "Application of Hydraulics to Agricultural Machinery," J. C. McNeice, 7.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Dec. 18.—ORDINARY MEETING: Great George Street, Westminster, London, S.W.1, "Post War Developments in the Coal Mining Industry," Andrew Young, H. A. Longden and B. L. Metcalf, 5.30 p.m.
Wed., Dec. 19.—YORKSHIRE ASSOCIATION: Hotel Metropole, Leeds, "The Design of Horizontal Flow Circular Settling Tanks," J. D. Thomson; "The Opening Out and Re-decking of Burnigill Tunnel," F. Jenkins, 6.15 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Dec. 14.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "The Teaching of the Fundamentals of Transistor Circuits to Students of Electrical Engineering," opened by P. Godfrey, 6 p.m.
Tues., Dec. 18.—MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, Discussion on "Breakdown in Dielectrics," opened by C. G. Garton and J. H. Mason, 5.30 p.m.——S.E. SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, "A Description of a Medium-Sized Industrial Electrical Distribution System," R. W. Robinson, 7 p.m.
Wed., Dec. 19.—SUPPLY SECTION: Savoy Place, London, W.C.2, "Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33kV and Above," A. Morris Thomas and D. F. Oakeshott, 5.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

To-day, Dec. 14.—JOINT MEETING: Robert Gordon's Technical College, Aberdeen, "Experiences with Welded Hulls," J. Turnbull, 7.45 p.m.
Tues., Dec. 18.—39, Elmbank Crescent, Glasgow, "Experiences with Welded Hulls," J. Turnbull, 6.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Mon., Dec. 17.—N.E. COAST BRANCH: Institute of Mining and Mechanical Engineers, Neville Street, Newcastle upon Tyne, 1, "Brains Trust," 6.30 p.m.
Tues., Dec. 18.—SCOTTISH BRANCH: Scottish Building Centre, 425, Sauchiehall Street, Glasgow, C.2, "Heating and Ventilating of Factories," D. T. Jenkins, 7 p.m.——LONDON ASSOCIATE MEMBERS, GRADUATES AND STUDENTS' BRANCH: Junior Institution of Engineers, Pepys House, 14, Rochester Row, London, S.W.1, Discussion, "What's the Answer?" 6.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Dec. 19.—GENERAL MEETING: Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Some Considerations on the Problem of Heating British Railways Coaches," F. J. Pepper, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Dec. 14.—GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, James Clayton Lecture, "Mechanical Breathing Machines," G. T. Smith-Clarke, 6 p.m.
Sat., Dec. 15.—LONDON GRADUATES' SECTION: Visit to National Physical Laboratory, Teddington, 2 p.m.
Mon., Dec. 17.—DERBY A.D. CENTRE: Midland Hotel, Derby "A Review of Hydro-Kinetic Fluid Drives and their Possibilities for the British Motor Industry," J. G. Giles, 7 p.m.——SCOTTISH A.D. CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "B.R.M. Car," A. F. Rivers Fletcher, 7.30 p.m.——MIDLAND GRADUATES' SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "How Cinematography Began," Brian W. Coe, 6 p.m.
Tues., Dec. 18.—INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion "Case Studies from the Application of Planned Maintenance," 6.45 p.m.——WESTERN BRANCH: Technical College, Swindon, "The Experimental Turbo-Diesel Locomotive," F. L. Picard, 7.30 p.m.
Thurs., Dec. 20.—YORKSHIRE GRADUATES' SECTION: Chemistry Lecture Theatre, The University, Leeds, "Plastics in Aeronautical Engineering," J. G. Carter, 6.30 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., Dec. 20.—Geological Society, Burlington House, Piccadilly, London, W.1, "A Field Method for the Rapid Estimation of the Oxides of Niobium and Tantalum in Black Sand Concentrates," H. C. Curwen; "Laboratory Studies on the Beneficiation of Some Ferruginous Manganese Ores of India for the Production of Ferromanganese," P. I. A. Narayanan and G. V. Subramanya, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Dec. 14.—W. WALES SECTION: Central Library, Alexandra Road, Swansea, Films of Automatically Controlled Machines, 7.30 p.m
Sat., Dec. 15.—N.E. GRADUATES' SECTION: Works Visit to James A. Jobling and Co., Ltd., Wear Glass Works, Sunderland, 10 a.m.
Mon., Dec. 17.—DERBY SECTION: College of Art, Green Lane, Derby, "The Technique and Application of Tungsten Carbide," F. H. Bates, 7 p.m.——N.E. SECTION: Neville Hall, Newcastle upon Tyne, Film Evening, 7 p.m.
Thurs., Dec. 20.—SOUTHERN SECTION: Polygon Hotel, Southampton, "Transfer Machining," A. J. Sephton, 7.15 p.m.——LONDON SECTION: Royal Empire Society, Northumberland Avenue, London, W.C.2, "The Production of a Technical Journal," R. Hutcheson, 7 p.m.——GLASGOW SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Metallurgy and the Production Engineer," T. G. Strong, 7.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Dec. 14.—INAUGURAL MEETING: Pepys House, 14, Rochester Row, London, S.W.1, Presidential Address, "Fuel Economy and Combined Heat-Electric Generation," Bryan Donkin, 7.30 p.m.
Fri., Dec. 21.—INFORMAL MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The J.I.E.: Past, Present and Future," J. Foster Petree, 7 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Dec. 14.—Mining Institute, Newcastle upon Tyne, "M.V. Bergensfjord," K. Haug and N. Carter, 6.15 p.m.

OLD CENTRALIANS

To-day, Dec. 14.—Mapleton Restaurant, Coventry Street, London, W.1, "Speech," Colin Cherry, 12.45 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., Dec. 20.—ALL-DAY SECTION LECTURE: Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Transonic Wind Tunnel Testing Techniques," introductory papers by H. F. Vessey, R. Hills, J. A. Kirk, F. O'Hara and F. E. Roe, 10 a.m.

Advanced Engineering Courses

Transistor Physics and Transistor Applications. SOUTH EAST LONDON TECHNICAL COLLEGE, Lewisham Way, London, S.E.4. Course of eight lectures commencing February 7. Thursdays from 7 p.m. to 9 p.m. Fee £1.